METALLURGIA

THE BRITISH JOURNAL OF METALS

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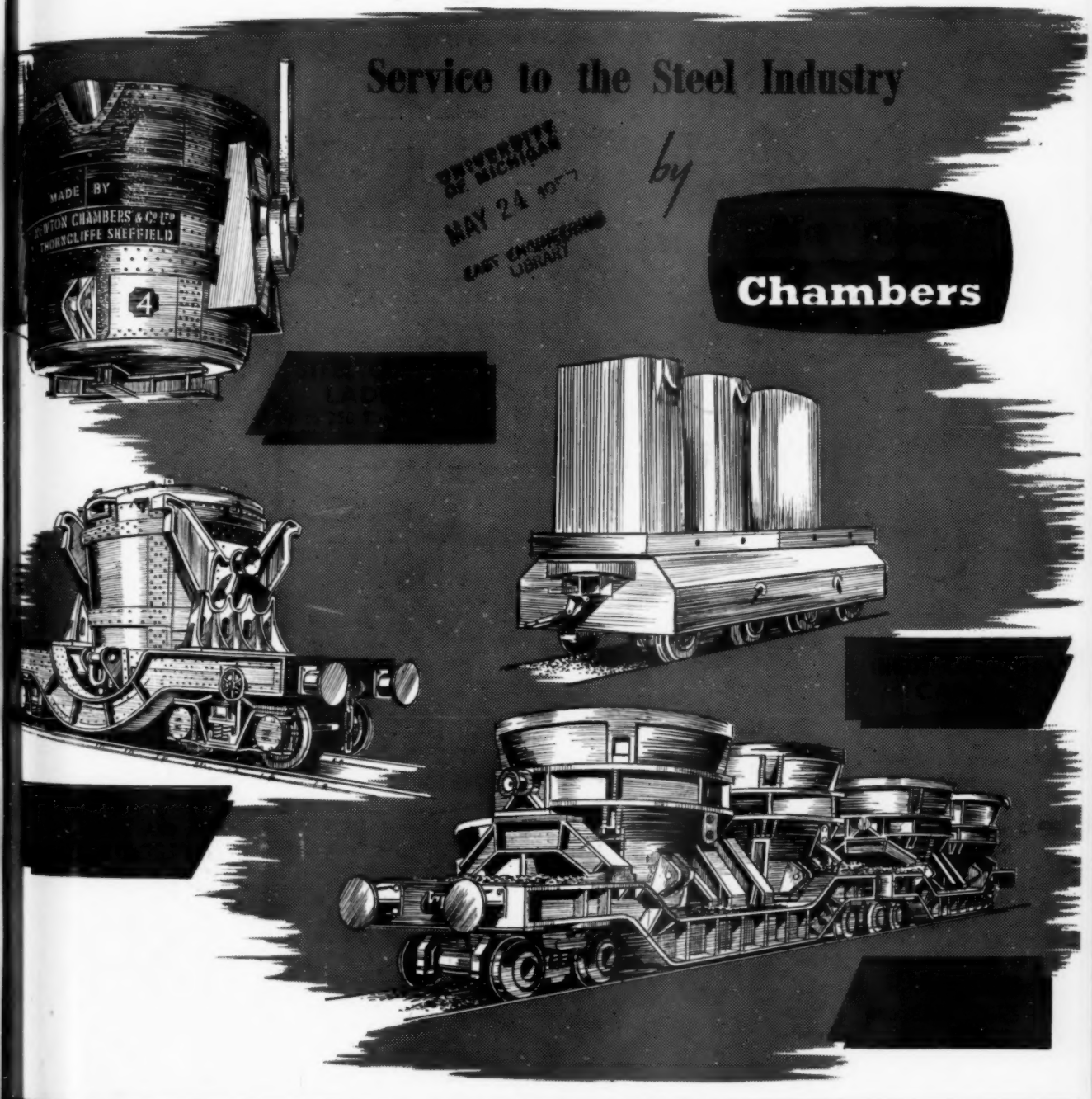

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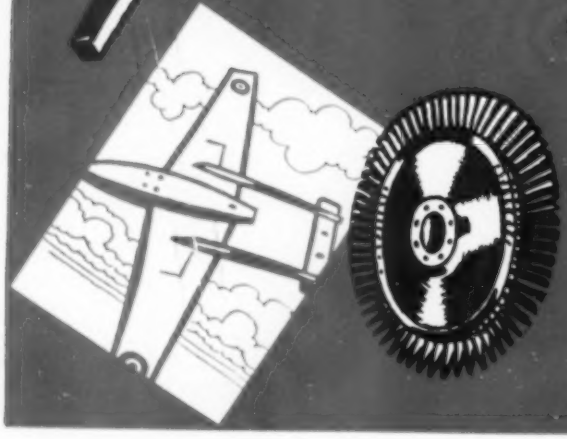

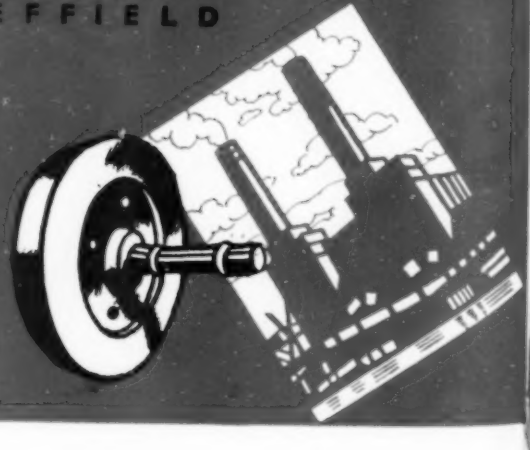

METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

MAY, 1957 Vol. LV. No. 331

Soviet Steel

IN the years immediately preceding the last war, those who "knew a man who had collided with a plywood tank on one of Germany's autobahn" were legion. Came the spring of 1940 and these self same "plywood" tanks rolled back the armies of the Low Countries, France and Britain and occupied the whole of the western seaboard of Europe. We were quite willing to believe that German rearmament was largely mythical—because we wanted to—and in the days when Russia was completely cut off from the Western World our mental attitude towards the Five Year Plan figures was one of scepticism, because we were not anxious to accept the fact that Soviet methods could be as effective as was claimed. Nobody who has taken part in the recent visits to Russia of European steel experts will any longer cherish any false impressions that the figures for steel production were mere propaganda, that the targets were unobtainable, or that the industry was inefficient.

In the current issue of *Steel Review** there is presented a first hand account of the Russian steel industry by three members of recent steel missions to the Soviet Union, which shows that the Russians have set themselves, and have maintained, a high standard of production and practice in their coke ovens, blast furnaces, and open hearth steel plant, but that they are somewhat less advanced in certain aspects of rolling mill technique. Up to 1955 there were, apparently, only two continuous hot strip mills in operation, one of which was pre-war American built, and the other, rolling only medium widths, was taken as reparations from Germany. This compares with three wide strip mills in the United Kingdom and eight in European Coal and Steel Community countries. A further wide strip mill came into operation in Southern Russia during 1955, and the Russian built mill at the new Polish steelworks near Cracow has also come into production. This disparity is lessened, too, when one considers that flat products find widespread application in consumer goods—motor cars, refrigerators, etc.—and the Soviet Union, with its lower standard of living, needs proportionately less of them. Statistics show that 39% of deliveries in the Western European home market are accounted for by flat products, while in Russia the figure is only 21%; in the United States flat product consumption amounts to about 53% of the total.

The *per capita* home consumption of steel in Russia in 1956 was 235 kg., as compared with 385 kg. in the United Kingdom and 602 kg. in the United States, so that there is ample scope for a continued increase in the proportion of world output arising in the Soviet Union. In 1939 it was 13%, but by 1956 it had risen to 17%, while the planned figures for 1960 will increase the figure to just under 18%. Increased output is unlikely to be held back by raw materials problems, as Russia has ample supplies of coking coal and iron ore, but the situation in Eastern Europe is not so favourable on this score.

In 25 years the industry has increased its production by over 600% to 40 million tons per annum, and in the next five years proposes a further 23 million ton increase. How is the industry organised to cope with this rapid development? The key unit is the Ministry of Iron and Steel in Moscow, which controls the whole heavy iron and steel industry. The Ministry is divided into sections covering the three main steelmaking areas, and sections dealing with quality steels, design and engineering, raw materials, labour, etc. It receives from the Central Planning Authority of the U.S.S.R. its general policy governing the amount of steel the industry will be required to produce by the end of the Five Year Plan, which it then translates into greater detail, devising the methods by which increasing outputs are to be achieved. Complete centralised control has its advantages in the design and construction of new plants. The Ministry has, during the last 20 years, laid down many new plants, and is by now well organised for the job.

In the works themselves the management team is headed by a Works Director, who, besides being responsible for the running of the plant, also controls the adjacent town. The Director has four or five Deputy Directors responsible to him for various aspects of the work, all of whom will have worked at a number of plants. Only the Director is appointed by the Ministry, and the members of the mission got the impression that Works Directors do not consider their freedom to manage is unduly restricted, nor that they are being controlled by men who do not know their job. The latter is hardly surprising, since all the senior staff of the Ministry have themselves been plant managers of one kind or another.

Considerable use is made of standards for measuring the efficiency of, and exercising control over, the various factors in the plants. Manning and performance standards for the plant are laid down by the Design and Planning Department of the Ministry in Moscow, and wage incentives are fixed by work measurement. Standards are reviewed annually and, by comparing the operation of one plant with another, operations in the industry are carefully measured and controlled.

The affinity of the bosses to the workers is a help in building up loyalty and morale in a large organisation. With the recent relaxation of a number of controls and the relative liberalisation which has set in, the element of fear as an incentive to work has largely disappeared. There now appear to be two main inducements: the first, and probably the strongest, is the wages system, which consists largely of properly measured incentives which rise sharply as results improve; the second is the lesson driven home from early youth, by every device of propaganda, that hard work and the achievement of production plans are sacred to every patriotic Russian.

The Works Director and his deputies are highly paid, and after taxation (the rate of which remains constant after a certain modest income level) their net remunera-

* No. 6, April, 1957.

tion is generally considerably higher than that of the General Manager of a British plant, or his chief assistants. On the shop floor, the differential between the highest and the lowest paid workers in the industry is nearly twice as big as the normal differential in British or American steelworks, and in addition the highest paid man in Russia will generally pay less direct tax than his opposite number in the other two countries. Quite apart from money incentives, workers are exhorted to achieve their targets, and considerable attention is also paid to communicating to workers what is expected of them under the Five Year Plan.

Under the foregoing conditions the productivity figure for 1955—57 tons per man year—is slightly below the present average in the British and German industries, and considerably below the 170 tons per man year in the United States. The attention which is being paid in Russia to technical development, and to the installation of automatic control devices, will lead in the next few years to an increased output with less than proportionate increases in manning. Unless great strides are made in this country, it seems likely that productivity in the Russian industry will surpass our own in quite a short time, and may even come within striking distance of the American figure in a longer period.

The expansion and development of the Russian steel industry results from the intensive application of the accumulated technical experience of the Western World, combined with the native genius and knowledge of the Russian engineer. There should not be forgotten, however, a factor which may be regarded as distinctly unique. In discussing this factor in *Steel Review*, Dr. T. P. Colclough summarises the essential difference between the Russian and Western steel industries as follows: "In most countries, the steel industry has been based on the result of individual inventions or discoveries and has grown to meet the demands of industry. Capital requirement has been provided by private enterprise and the progress of the industry has been controlled to a large degree by the general economic conditions prevailing in the industries whose needs it is the function of the steel industry to serve. Under such conditions the rate of progress must be variable and much of the capital and individual effort invested inevitably fails to meet its due reward. On the other hand, the steel industry in Russia has been deliberately planned not to meet existing demands but to make possible the creation of new engineering and industrial activities. The Soviet steel industry throughout the whole period has been assured of a steady outlet for its products and there has always been every incentive, both internal and external, to strive for maximum production and efficiency. The capital necessary for the new installations has been readily forthcoming, and the growth of the steelworks has been matched by the provision of all the necessary facilities for transport and the supply of power and raw materials.

"Under these conditions, every plant unit has been assured of a full economic load, and with this combination of circumstances the splendid records of achievement might be regarded as the natural outcome."

Diamond Die Report

EARLY in 1950 the British Diamond Die Federation received a report from its Technical Committee upon the subject of die performance, which was based on statistics submitted voluntarily in a prescribed form by a large number of its members engaged in the drawing of various metals. This report established a measure of the degree of variability which provided a yardstick for wire drawers to assess, and therefore to improve, the performance of their dies. The Council of the Federation decided that this work should be followed up by undertaking comparative tests of diamond dies made in this country with those made elsewhere.

The primary object of the Council was to establish that die users who had to depend on a limited number of suppliers in the United Kingdom were obtaining dies which were at least the equal of those which could be obtained overseas. As the test progressed, however, it became evident that it would become the most comprehensive and carefully controlled investigation into die performance ever undertaken in this country, and the original objective became secondary to that of seeking to establish the causes of poor die performance and of improving the design and specification of diamond dies.

The earlier report of the Technical Committee had indicated that a comparison between English and foreign dies could best be achieved in copper drawing, and that the minimum number of dies required would be about twenty. The size of die chosen was 0·0076 in. and three dies for copper wire drawing of this size were, therefore, purchased from each of two American, one Belgian, one Dutch, and two French Die makers, together with five dies from two British die makers. These purchases were privately arranged in such a manner as to avoid special selection of dies by the various makers, the makers' distinguishing marks were erased, and the dies were numbered at random from 1 to 23.

Whereas the investigation carried on by the Technical Committee related solely to dies for copper wire drawing, it was subsequently learned that a stainless steel wire drawer was independently investigating the design and performance of dies obtained in the United Kingdom. A brief summary of the work done and conclusions drawn by this user is included in the report which has been prepared on the work of the Technical Committee. It is hoped that copies of the report will be made available to the public.

Sulphur Recovery at Copper Cliff

A FURTHER advance in its programme for maximum utilisation of Sudbury District ores has been made by The International Nickel Co., of Canada, Ltd., with the conclusion of an agreement with Texas Gulf Sulphur Company for the operation of a pilot plant at Copper Cliff to investigate processes for the recovery of elemental sulphur from sulphur-dioxide-bearing gases. The joint pilot plant will be built near the site of Inco's new iron ore recovery plant. It will consist of two sections, one for scrubbing and cleaning gas, and one for reduction of the sulphur dioxide to elemental sulphur. The investigation into the feasibility of the project may extend for several years. If the pilot plant findings indicate that commercial production of sulphur at Copper Cliff is economically possible, plans will be formulated for production by Texas Gulf on a basis of many hundreds of tons of sulphur per day.

An Investigation into the Catastrophic Corrosion of a Flake Graphite Cast Iron in Carbon Dioxide Containing a Small Amount of Carbon Monoxide

By Miss S. R. Billington, A.R.S.M., B.Sc., and B. C. Woodfine, B.Met., Ph.D.

(*Engineering Materials Laboratory, G.E.C./Simon-Carves Atomic Energy Group*)

A pearlitic flake graphite cast iron has been found to undergo severe oxidation in times of less than 3,000 hours in a CO-CO_2 equilibrium mixture under a pressure of 200 p.s.i.g. at 525° C. The oxidation behaviour of the iron in both CO_2 and CO-CO_2 mixtures at temperatures up to 525° C. is described and a mechanism is suggested to account for the observed phenomena.

OXIDATION tests in CO_2 and CO-CO_2 mixtures have been carried out on a range of ferrous alloys to obtain data relevant to the design of CO_2-cooled, graphite-moderated nuclear reactors. In the course of these experiments some rather unexpected results were obtained with a fine flake graphite pearlitic cast iron in a CO-CO_2 mixture at 525° C. A brief description of this effect has been given by Dennis,[1] and the purpose of the present paper is to describe in detail the results obtained in the oxidation tests on the cast iron and to offer a tentative explanation of the observed phenomena.

The oxidation tests were carried out over the temperature range 375–525° C. under a gas pressure of 200 p.s.i.g. (i.e. approximately 14·5 atm.).

Experimental

The cast iron tested was supplied in the form of 1 in. diameter bars, and had the composition: C, 2·67%; Si, 1·97%; P, 0·079%; S, 0·025%; Mn, 0·61%; Cr, 0·16%; and Cu, 1·54%.

The specimens used for the weight-gain measurements were discs cut transversely from the bars with a surface area of about 13 sq. cm. and a weight of about 11 g. In addition, small segments of discs were included for subsequent metallographic examination. Before oxidation all the specimens were polished on 150 mesh silicon carbide papers and degreased in hot carbon tetrachloride.

The CO_2, which was generated from Cardice, was dried by activated alumina to less than 0·003% moisture by weight. The CO was obtained from cylinders, the major impurity in this gas being 0·8% nitrogen. The

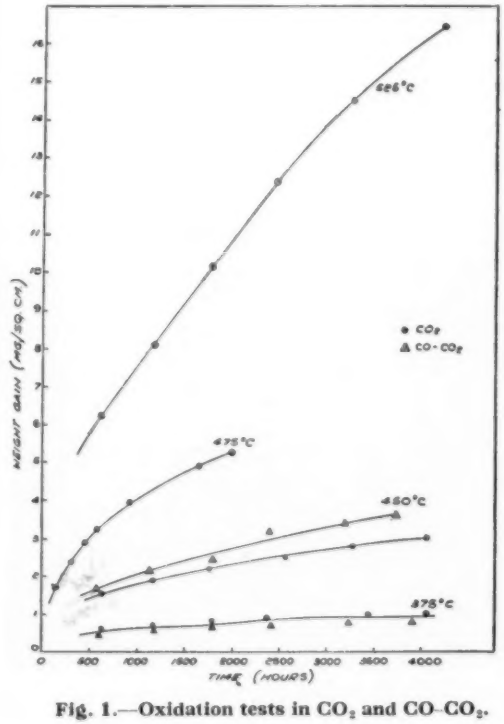

Fig. 1.—Oxidation tests in CO_2 and CO–CO_2.

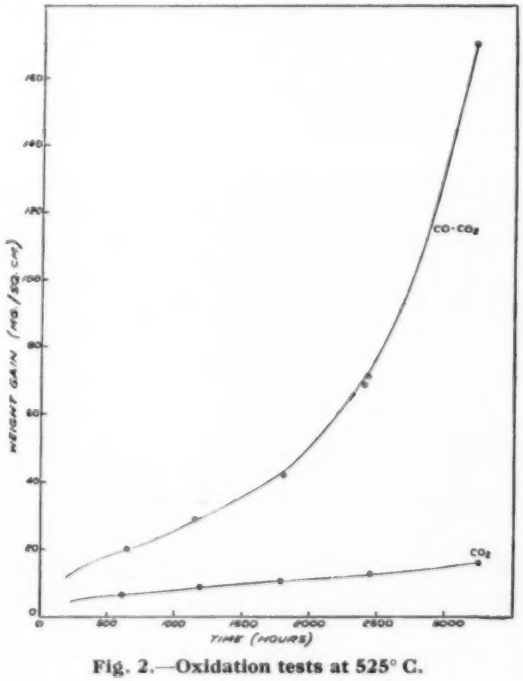

Fig. 2.—Oxidation tests at 525° C.

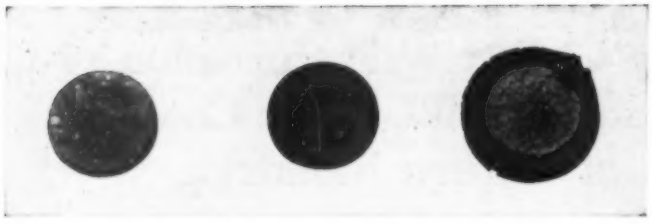

Fig. 3.—Specimens after approximately 3,000 hours at 375, 450 and 525° C. $\times \frac{2}{3}$

CO-CO_2 mixtures used were nominally those which would be in thermal equilibrium with graphite at the appropriate temperature under a pressure of 200 p.s.i.g., i.e. the gas should have been saturated with respect to carbon under the test conditions. However, considerable difficulties were encountered in maintaining a constant gas composition at the high pressures used, so that the gas mixture may well have been super-saturated with respect to carbon for various periods of time during the tests.

The oxidation tests were carried out in stainless steel pressure vessels which were totally enclosed in thermostatically controlled furnaces, and the temperature was maintained in the vessels to within ± 7° C. Throughout the test a slow flow of gas (approximately 0·05 lit./min. was passed through the pressure vessels.

Oxidation Results

Oxidation tests were carried out at 375°, 450°, 475° and 525° C. in dry CO_2 and at 375°, 450° and 525° C in dry CO-CO_2 mixtures. The results of the main series of tests are shown in Figs. 1 and 2 as weight-gain *v.* time curves, the plotted points being the mean values for duplicate specimens.

For duplicate weight-gain specimens in the same pressure vessel, the differences in results were in general not greater than 10%. However, in short time repeat tests at 450° and 525° C., variations of up to 50% were observed between the results obtained in different tests.

It is clear from Figs. 1 and 2 that although at 375° and 450° C. there is little difference between the results obtained in CO_2 and in the CO-CO_2 mixtures, at 525° C. the rate of oxidation in the CO-CO_2 mixture is very much greater than that in CO_2. Fig. 2 also shows that the rate of oxidation at 525° C. in the CO-CO_2 mixture is not constant but increases with time.

The appearance of specimens oxidised for prolonged periods in the CO-CO_2 mixtures is shown in Fig. 3.

Metallographic Examination of Oxidised Specimens

The microstructure of the cast iron before oxidation is shown in Figs. 4 and 5. The structure is fully pearlitic, with fine graphite flakes, and particles of a copper-rich phase are randomly distributed in the matrix.

Oxidation Tests in CO_2

Oxidation Tests at Temperatures up to 475° C.

The microstructure of the iron after 3,000 hours at 450° C. is shown in Fig. 6, and it is clear that the pearlite shows little sign of spheroidisation and that no secondary graphite has been formed. There was similarly little change in the microstructure after 2,000 hours at 475° C.

The scale formed on specimens oxidised at temperatures up to 475° C. is firmly adherent to the metal, and is almost entirely free from cracks. Those cracks which are present may be reasonably attributed to damage suffered during the sectioning and mounting of the specimens. The scale formed at and below 475° C. consists of two zones of approximately equal thickness, the outer zone being lighter in colour than the inner (Fig. 7). Many of the graphite flakes which are present in the inner scale layer have undergone a drastic change in appearance (Fig. 7), and appear to have disintegrated. In no case were graphite flakes observed to penetrate into the outer zone of the scale. Some slight penetration of oxide has occurred down the graphite flakes at

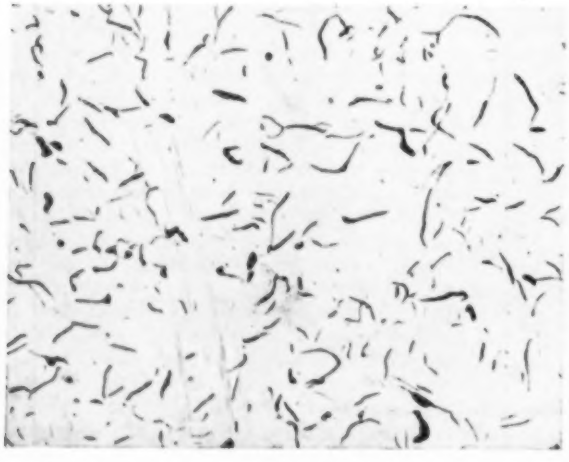

Fig. 4.—As received condition. Unetched. × 100

Fig. 5.—As received condition. Etched 2% nital. × 750

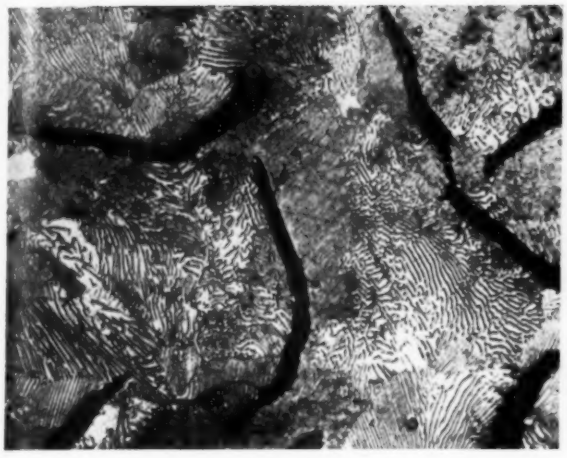

Fig. 6.—Typical microstructure after 3,000 hours in CO_2 at 450° C. Etched 2% nital. × 750

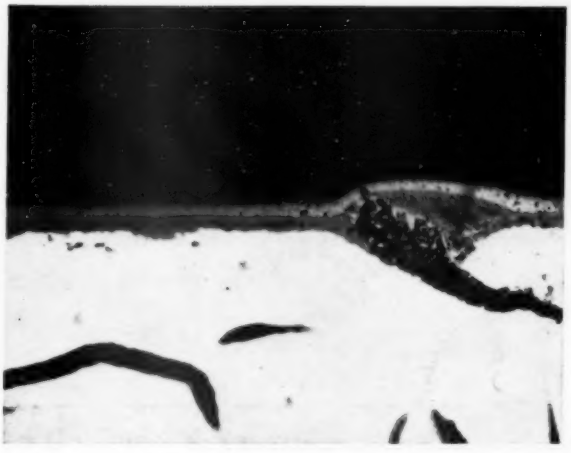

Fig. 7.—Two-layer oxide film with "burst" graphite flake after 2,500 hours in CO_2 at 450° C. Unetched. × 500

450° C. (Fig. 7) and at 475° C. (Fig. 9). The penetration is greater at the higher temperature.

High power examination of the outer scale zone shows that it is essentially structureless (Fig. 8), although it does contain a number of small black areas that are probably pores. As shown in Fig. 8, the inner scale zone is a duplex structure consisting of a light matrix with darker particles and filaments distributed within it. Fig. 8 also shows that the graphite flakes in the inner zone are surrounded by a structureless layer, and that this layer and the matrix of the inner zone are continuous with the outer zone of the scale. Thus, the only difference between the two zones in the oxide appears to be the presence of the darker second phase in the inner zone. The general appearance of the filaments of the second phase in Fig. 8 suggests that they have been formed from the carbide plates of the pearlite. This is confirmed by Fig. 9 which shows the conversion of carbide plates ahead of the metal-oxide interface into the dark second phase. Decomposition of the carbide will give graphite and either iron or iron oxide, so that the second phase in the scale must be graphite. Thus, in the scale the outer layer is oxide and the inner layer a mixture of oxide and graphite.

As would be expected from the fact that copper does not oxidise in CO_2 or CO-CO_2 mixtures, the copper-rich particles present in the original matrix are found embedded in the scale. Traces of a copper-rich phase were also occasionally observed as films at the oxide-metal interface.

In an X-ray diffraction examination of a specimen oxidised at 375° C., the phases identified in the scale were Fe_3O_4 and Fe_2O_3, although the lines of the latter phase were described as medium weak. With a specimen oxidised at 450° C. the only phase identified was Fe_3O_4.

Oxidation Tests at 525° C.

The structure of the iron after prolonged oxidation in CO_2 at 525° C. is illustrated in Fig. 10. This shows that complete spheroidisation of the carbide has taken place and that some deposition of secondary graphite has occurred on the primary graphite flakes.

Fig. 8.—Lamellar structure of the inner oxide zone after 2,000 hours in CO_2 at 475° C. Etched 2% nital. × 2,000

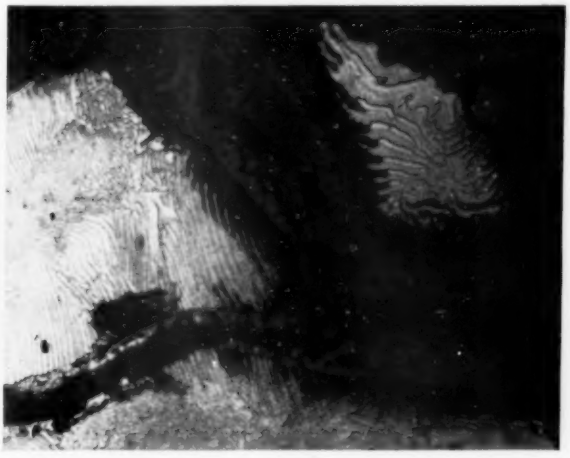

Fig. 9.—Graphitisation of cementite lamellae after 2,000 hours in CO_2 at 475° C. Etched 2% nital. × 1,200

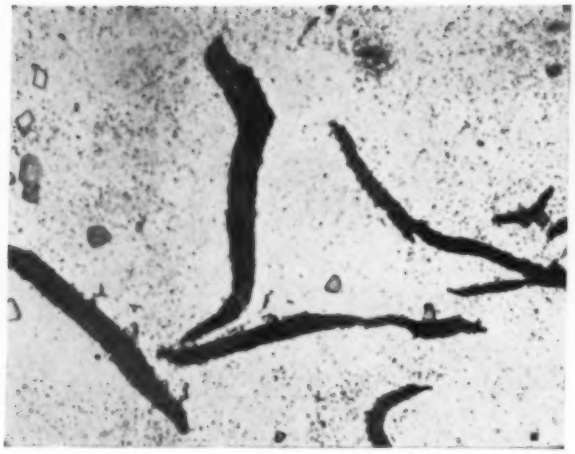

Fig. 10.—Typical microstructure after 4,230 hours in CO_2 at 525° C. Etched picral. × 750

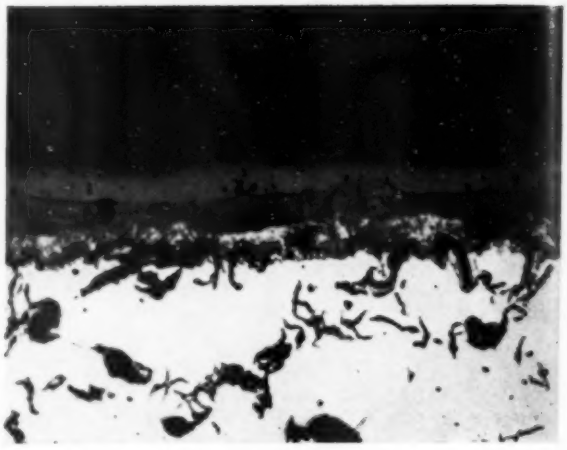

Fig. 11.—Three-layer oxide film after 3,500 hours in CO_2 at 525° C. Unetched. × 250

The scale formed on the iron at 525° C. consists of three zones of approximately equal thickness (Fig. 11). The outer two zones are identical in appearance with those formed at the lower temperatures, but the inner zone is a subscale containing a mixture of oxide and metal. As with the specimens oxidised at the lower temperatures, no graphite flakes were observed in the outermost zone, and many of those flakes which extended into the inner two layers had apparently disintegrated.

As before, the middle zone of the scale is a mixture of oxide and finely divided graphite. Graphitisation of the carbide ahead of the third zone interface was only observed in the areas where the original carbide lamellae had persisted. The subscale was observed to contain appreciable amounts of the copper-rich phase both in the form of irregular particles and as films along the interface between the subscale and the metal.

The junction between metal and subscale for a specimen oxidised for 3,500 hours at 525° C. is shown in Fig. 12, from which it can be seen that the graphite flakes adjacent to the metal surface are surrounded by a layer of oxide similar in appearance to the outer scale zone. Outside the oxide layer, and separated from it by a thin dark film of indeterminate structure (*A* in Fig. 12), is a broad zone (*B*) enveloping a number of graphite flakes. This zone has etched slightly darker than the surrounding ferrite-carbide matrix, and is separated from the matrix by a distinct boundary. Examination of the centre of Fig. 11 reveals that zone *B* appears to be continuous with the subscale. It was found that nearly all the graphite flakes adjacent to the metal surface were surrounded by dark etching zones. In preparing the metallographic specimens it was noticed that these zones had a tendency to stain when water was used in the final polishing operations. Although in Fig. 12 carbide particles appear to be absent from zone *B*, repolishing followed by prolonged etching in picric acid showed that carbides could be distinguished within the zone.

Fig. 12.—Edge of specimen showing oxide film and adjacent metal after 3,500 hours in CO_2 at 525° C. Etched 2% nital. × 1,200

The apparent continuity of zone *B* with the subscale in Fig. 12 suggested that zone *B* might be high in oxygen, and that this difference in composition was responsible for its slightly different etching behaviour as compared with the surrounding matrix. This suggestion was confirmed by etching the specimens in a freshly prepared boiling alkaline sodium chromate solution, which reagent has been shown[2] to differentiate between areas of high and low oxygen content by leaving the oxygen-rich areas unattacked.

The interface between metal and scale in a specimen oxidised for 3,500 hours at 525° C. and etched in boiling sodium chromate is illustrated in Fig. 13, which shows that the zones surrounding the graphite flakes have not been attacked and are, therefore, zones of high oxygen content. Although the subscale appeared to be continuous with the zones round the graphite flakes (Fig. 12), it was found that the metal in the subscale was attacked by the chromate solution and coloured red. As the chromate solution is highly oxidising to the metal and the subscale has a high copper con-

tent, this difference in etching behaviour may be explained by the production of surface film of Cu_2O on the metal. The formation of this film apparently obscures any effects due to oxygen.

Although the examination of specimens etched in the normal reagents had indicated that only the graphite flakes adjacent to the metal surface were surrounded by oxygen-rich zones, examination of the same specimens etched in the chromate reagent revealed the presence of unattacked zones around occasional graphite flakes well removed from the surface. This demonstrates that some oxygen penetration has occurred down the graphite flakes in the specimens oxidised in CO_2 at 525° C., but the absence of any oxide around the graphite shows that such oxygen penetration is very limited. The sensitivity of the chromate etching reagent to oxygen concentration is not known, and it is possible that the reagent can detect extremely small differences in oxygen content.

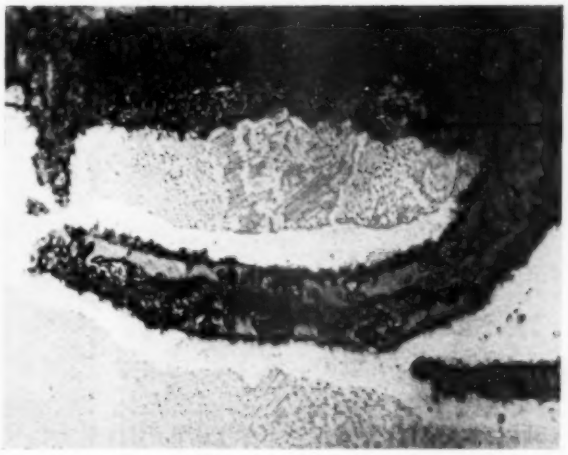

Fig. 13.—Oxygen-rich zones around graphite flakes after 3,500 hours in CO_2 at 525° C. Etched 30 seconds in boiling alkaline chromate. × 1,200

The innermost scale layer in Fig. 12 shows a good example of a graphite flake (*C*) which appears to have completely disintegrated on becoming surrounded by the scale. The remains of the flake are embedded in an area of light oxide identical in appearance to that forming the outer zone of the scale and to that around the graphite flakes connected to the metal surface.

Electron diffraction and X-ray examination of a specimen oxidised for 4,000 hours at 525° C. in CO_2 showed that only Fe_3O_4 was present in the scale. In addition to Fe_3O_4 a face-centred cubic phase, presumably the *epsilon* copper-rich phase, was detected in the subscale. Chemical analysis of the sample showed a carbon content of 2·9% as compared with 2·6% in the original metal.

Oxidation in the CO-CO_2 Mixtures

Oxidation Tests at 375° C. and 450° C.

Specimens oxidised in the CO-CO_2 mixtures at 375° and 450° C. were found to be identical with those oxidised in CO_2 for equivalent times at the same temperatures.

Oxidation Tests at 525° C.

As would be expected, in the specimens oxidised in the CO-CO_2 mixture the carbide plates in the pearlite had spheroidised to the same extent as in specimens oxidised for similar times in CO_2. However, it was observed that, even with specimens that had only been oxidised for 600 hours in the CO-CO_2 mixture at 525° C., films of oxide were associated with nearly all the graphite flakes in the metal, and not only with those adjacent to the surface. With oxidation times of more than 2,000 hours, oxide was associated with the graphite flakes over the whole specimen. All the graphite flakes which showed the presence of oxide were also surrounded by dark etching zones similar to zone *B* in Fig. 12. A typical area from the centre of a specimen oxidised for 3,800 hours at 525° C. in the CO-CO_2 mixture is shown at low power in Fig. 14 and at high power in Fig. 15. A similar specimen which has been etched in boiling sodium chromate is shown in Fig. 16, which demonstrates the extent to which the graphite flakes are surrounded by oxygen-rich areas.

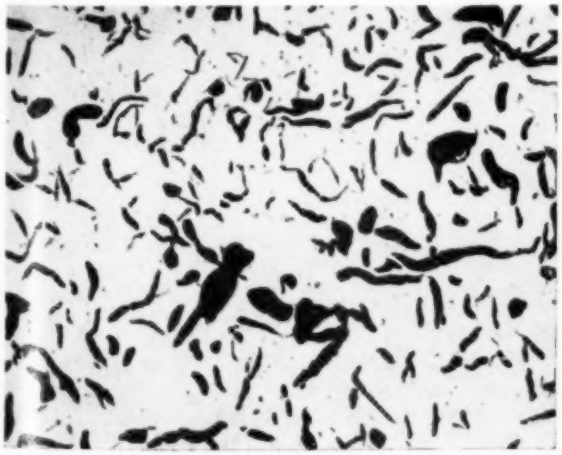

Fig. 14.—Typical microstructure after 3,800 hours in CO–CO_2 at 525° C. Unetched. × 100

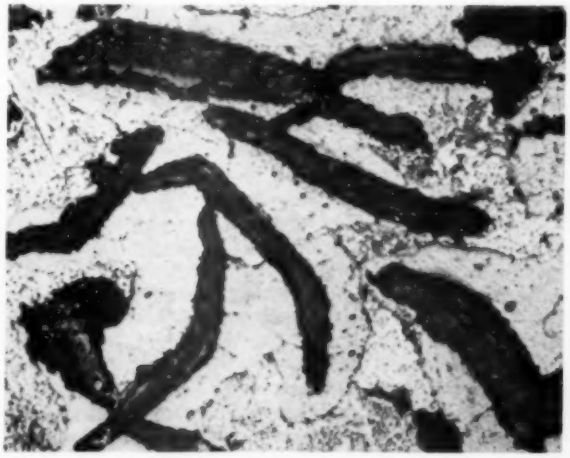

Fig. 15.—Typical microstructure after 3,800 hours in CO–CO_2 at 525° C. Etched 2% nital. × 750

Fig. 16.—Oxygen-rich zones around graphite flakes after 2,654 hours in CO–CO_2 at 525° C. Etched 30 seconds in boiling alkaline chromate. ×750

Fig. 17.—Cracking in the oxide film after 2,500 hours in CO–CO_2 at 525° C. Unetched. × 250

Examination of Fig. 15 reveals that secondary graphite appears to have been deposited directly on some primary graphite flakes, but that in many places there is a dark layer of what may be secondary graphite, or more probably a mixture of oxide and graphite at the oxide-metal interface.

The scale formed on specimens oxidised in the CO-CO_2 mixture contains large numbers of cracks both perpendicular to and parallel to the metal surface. The cracks are particularly frequent on the curved edge of the disc specimens, where the thickness of the oxide is considerably greater than on the flat surfaces of the disc. As with specimens oxidised in CO_2 at the same temperature, the scale produced in the CO-CO_2 mixture at 525° C. is made up of three zones. However, the subscale and outer zone are both thinner than for corresponding oxidation times in CO_2, although the centre zone is very much thicker. The thickness of the outer zone is reasonably constant but the centre zone and the subscale vary considerably in thickness. A comparison between the relative widths of the three zones in specimens oxidised at 525° C. in CO_2 and in the CO-CO_2 mixture is given in Table I.

TABLE I

Gas	Time (hr.)	Width of Zone ($\times 10^{-3}$ mm.)		
		Outer	Centre	Inner
CO_2	1,500	14	18–70	12
	4,000	18–26	35–70	9–14
CO-CO_2	1,500	7	230–260	3·5–7
	4,000	7	280–480	2–10

It was noticed that cracks in the centre zone of the scale which were parallel to the metal surface frequently had a thin layer of the outer scale zone on the surface nearest to the metal (Fig. 17). Examination of the centre scale zone at high power showed that in some areas the graphite was not present as lamellae or randomly distributed particles, but tended to be concentrated in layers separated by bands of the matrix oxide (Fig. 18).

Most of the graphite flakes which were present in the centre and inner scale zones appeared to be essentially undamaged and to have retained their original shape, (Figs. 18 and 19). This is in marked contrast to the disintegration suffered by nearly all the graphite flakes which are present in the corresponding scale zones in the specimens oxidised at 525° C. in CO_2 (*cf.* Fig. 12).

The presence of numerous undamaged graphite flakes in the scale formed in the CO-CO_2 mixture is shown in Fig. 20. This micrograph has been taken under polarised light, so that it only shows those flakes which have similar orientations. Rotation of the field in Fig. 20 revealed the presence of other flakes with different orientations.

In nearly all cases where a graphite flake extended to the boundary of the outer oxide zone, this zone was found to be cracked or to show extensive porosity at the tip of the flake (Fig. 19), so that the protective nature of the outer zone was extremely limited.

Examination of the metal-scale interface showed that severe penetration of oxide down the graphite flake had occurred in all specimens oxidised at 525° C. in the CO-CO_2 mixture. It was also found that the inner scale zone contained appreciable amounts of the copper-rich phase.

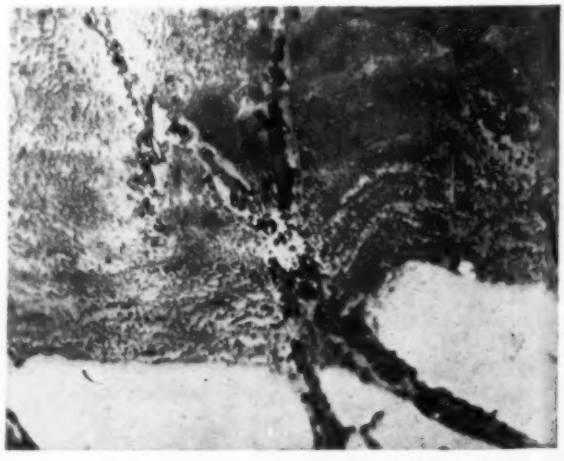

Fig. 18.—Contoured oxide film with unaffected graphite flakes after 3,000 hours in CO–CO_2 at 525° C. Unetched. × 750

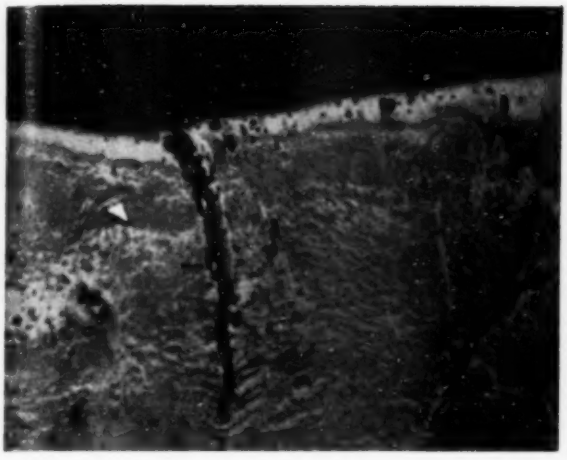

Fig. 19.—Penetration of graphite flake to the outside of the central oxide zone and cracking in the outer zone after 3,000 hours in CO–CO_2 at 525° C. Unetched. × 750

Fig. 20.—Penetration of graphite flakes through the oxide after 3,000 hours in CO–CO_2 at 525° C. Polarised light. × 250

Electron diffraction and X-ray examination of a specimen oxidised for 3,000 hours at 525° C. in the CO-CO_2 mixture revealed the presence of graphite at the outer surface of the scale and Fe_3O_4 in the body of the scale. A face-centred cubic phase, presumably the *epsilon* copper phase, was also found in the subscale.

Discussion

The most obvious differences in the structure of the scale and the metal between specimens oxidised in CO_2 and in the CO-CO_2 mixture at 525° C. are in (*a*) the thickness and continuity of the outer graphite-free oxide zone in the scale; (*b*) the extent of the break-up of the graphite flakes in the centre zone of the scale; and (*c*) the extensive oxide and oxygen-rich matrix zones around all the graphite flakes in the CO-CO_2 specimens. The diffusion of gas through graphite or down the interfaces between graphite and oxide will be very much more rapid than ionic diffusion in the scale. Thus, the simplest explanation for the high rate of oxidation observed in the CO-CO_2 gas mixture at 525° C. is that the very thin outer zone of graphite-free oxide does not prevent free access of CO_2 to the centre scale zone, and that the undamaged graphite flakes present in this zone then provide channels for the gas to penetrate into the metal. In CO_2 the outer graphite-free oxide zone is much thicker, and the graphite flakes in the centre zone tend to be broken up so that they do not offer to the gas the same free access into the metal.

For a complete explanation of the high rate of oxidation observed in the CO-CO_2 mixture it is, therefore, necessary to account for the differences in the thickness of the outer graphite-free oxide zone and for the differences in the behaviour of the graphite flakes in the scales. The outer graphite-free oxide layer can be produced by two processes: (*a*) the outward diffusion of iron ions and their conversion to oxide at the oxide-gas interface; and (*b*) the removal of graphite from the inner zone by the reaction $C + CO_2 \rightarrow 2CO$. In the CO-CO_2 mixtures the latter reaction should not have occurred unless the gas composition became deficient in CO, so that the thickness of the graphite-free oxide zone would be expected to be less than in CO_2. From Table I and Figs. 11 and 19, both the outward diffusion of iron and the removal of graphite would appear to be equally important in producing a thick graphite-free oxide layer. However, the situation is complicated by the fact that if CO_2 is penetrating down the graphite flakes then any iron ions diffusing outward might be converted to oxide before reaching the outer oxide-gas interface. Thus, the most important factor in producing a less protective scale may be the behaviour of the graphite flakes.

The disintegration of the graphite flakes in the specimens oxidised in CO_2 is difficult to explain. A graphite flake embedded in a scale produced by oxidation in CO_2 would be expected to be slowly converted to CO, either directly by reaction *in situ* with oxygen in the scale, or indirectly as the result of the removal of carbon from the oxide by reaction at the oxide-gas interface. The latter process would seem more likely, as direct oxidation could only proceed if CO diffused away from the graphite through the scale. However, it is not obvious how either process would cause the graphite flakes to disintegrate in the manner shown at *C* in Fig. 12. The graphite flakes in specimens oxidised in the CO-CO_2 mixture should theoretically show neither oxidation nor growth, so that it is easier to understand their role in providing easy access for the gas into the metal.

Although the CO-CO_2 mixtures were nominally in equilibrium with the graphite, the gas would be unsaturated and supersaturated with respect to carbon for various periods of time as the result of pressure and composition changes, but to what extent these fluctuations accelerated or retarded the oxidation of the iron is not known. However, it is considered that even if the CO-CO_2 mixture were maintained exactly at the equilibrium value the corrosion rate at 525° C. would still be substantially greater than in CO_2, because of the presence of graphite flakes in the scale and the non-protective nature of the outer oxide zone.

The increase in the carbon content of metal and scale shown by the specimens oxidised in the CO-CO_2 mixture may be partly explained in terms of the deposition of carbon from the high local concentrations of CO produced as a result of the oxidation process. The carbon content of the scale will also have been increased by carbon deposition from the gas phase on those occasions when the equilibrium amount of CO was exceeded in the

gas mixture. That such carbon deposition has occurred is shown by the electron diffraction results, which demonstrated the presence of graphite at the outer surface of the scale.

The fact that at 375° C. and 450° C. the oxidation rates in the CO-CO_2 mixtures are similar to those in CO_2 presumably means that very little penetration of the gases takes place down the graphite flakes at these temperatures. As at 375° C. and 450° C., the thickness of the outer oxide zone is not apparently affected by the presence of the CO, this outer zone has presumably been formed only by the outward diffusion of iron ions, and in the specimens oxidised in CO_2 graphite has not been removed from the inner zone.

Although Davies, Simnad and Birchenall[3] have deduced from the marker experiments carried out at about 900° C. that in Fe_3O_4 the rate of diffusion of iron is three times as fast as that of oxygen, the relative thickness of the outer zone in the cast iron specimens oxidised in CO_2 would seem to indicate that at lower temperatures the diffusion rates of iron and oxygen are more nearly equal. The situation is complicated in the present instance, however, by the presence of the graphite flakes and the graphite formed from the carbide in the specimen.

Conclusions

The principal observations that have been made on the cast iron specimens oxidised in CO_2 and in CO-CO_2 mixtures under a gas pressure of approximately 14·5 atm. at temperatures up to 525° C. may be summarised as follows :—

(*a*) The oxidation rates in CO_2 and in the CO-CO_2 mixture at 375° and 450° C. are very similar, but at 525° C. the rate of oxidation in the CO-CO_2 mixture is very much greater than in CO_2.

(*b*) The only phases detected in the scales by X-ray and electron diffraction examination were Fe_3O_4 and graphite (except in the specimen oxidised in CO_2 at 375° C. where a small amount of Fe_2O_3 was found).

(*c*) At temperatures below 475° C. the scales formed in both CO_2 and the CO-CO_2 mixture consist of an outer zone of Fe_3O_4 and an inner zone of (Fe_3O_4 + graphite).

(*d*) At 525° C. in both CO_2 and the CO-CO_2 mixture a subscale is formed in addition to the oxide and oxide + graphite zones.

(*e*) At 525° C. in CO_2 the three scale zones are of comparable thickness, but in the CO-CO_2 mixture the centre zone of oxide + graphite is very much thicker than either the outer zone or the subscale.

(*f*) In all cases graphite flakes are not present in the outer oxide zone of the scale, but only extend through the subscale and into the centre zone.

(*g*) The majority of the graphite flakes present in the scales formed in CO_2 appear to have disintegrated, whereas most of the flakes in the scale formed in the CO-CO_2 mixture at 525° C. are intact.

(*h*) At 525° C. in the CO-CO_2 mixture the outer oxide zone in the scale is cracked or shows extensive porosity at the tip of any graphite flake which extends to the inner boundary of the zone.

(*i*) In CO_2 at 525° C. only the graphite flakes close to the metal surface are enclosed in oxide and surrounded by an oxygen-rich matrix zone, but in the CO-CO_2 mixture at the same temperature these effects extend throughout the whole specimen.

(*j*) At 525° C. in the CO-CO_2 mixture substantial carbon deposition appears to have occurred in both metal and scale.

It is suggested that the high rate of oxidation observed in the CO-CO_2 mixture at 525° C. is due to the presence of undamaged graphite flakes in the scale and the very thin non-protective nature of the outer oxide zone. In CO_2 the outer oxide zone is much thicker and the graphite flakes in the centre zone of the scale have become disintegrated, so that they do not provide free access for the gas into the metal. If this explanation is correct, then it is clear that any flake graphite iron will show the same effect unless either the graphite flakes are not interconnected or the matrix is inherently resistant to oxidation. Spheroidal graphite iron would not be expected to show accelerated oxidation in CO-CO_2 mixtures for the obvious reason that the graphite spheroids are not interconnected.

Acknowledgments

The authors wish to thank Dr. W. E. Dennis, Chief Metallurgist of the G.E.C.-Simon-Carves Atomic Energy Group, for his encouragement and interest in the work, and Mr. C. G. Stevens for carrying out the oxidation tests. They would also like to thank their colleagues in the Engineering Materials Laboratory for helpful discussions. The X-ray, electron diffraction and chemical analyses were carried out by Mr. R. C. Chirnside, Mr. B. S. Cooper and Mr. H. P. Rooksby at the Research Laboratories of the General Electric Co. Ltd., Wembley.

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3 Davies, M. H., Simnad, M. T., and Birchenall, C. E., *Trans. A.I.M.E.*, 1953, **197**, 1250.

Opportunities for School Leavers

HALF a million boys and girls leaving school this summer will be aided in their choice of career by the " Directory of Opportunities for School Leavers," which will be distributed free to their schools. The book is a companion volume to the " Directory of Opportunities for Graduates " which was first published in January and reprinted in February of this year. The majority of the most important firms in British industry and commerce were included in the latter and it is expected that there will be similar support for the new publication. Full details of training schemes, age of recruitment, location of works, and a brief description of the firm and its products will be included in each entry.

B.T.H. Order

THE British Thomson-Houston Co., Ltd., has received an order valued at more than £1½m. for two 120,000 kW. C.M.E.R. turbo-alternator sets for the new Padiham " B " Power Station of the Central Electricity Authority. The turbines of these sets are to be designed to operate under steam conditions of 1,500 lb./sq. in. gauge at a temperature of 1,000° F. with re-heat to 1,000° F. The alternators will be hydrogen cooled.

Foil Testing

New Laboratory Wing Opened at Venesta's Silvertown Works

View of the testing laboratory showing the Karl Fischer apparatus on the right and the Ferranti viscometer in the centre background.

TODAY, research is vital to progress and this is particularly true in the foil rolling industry, which has expanded almost beyond recognition in the last decade to meet the rapidly increasing demand for foil for an ever widening number of end uses. With the opening of their new laboratory wing at Silvertown, Venesta, Ltd.—who roll one-third of the aluminium foil exported from this country—have established one of the largest and best equipped laboratories in the industry, and are able to offer what is believed to be the most comprehensive research and testing service to foil users.

The company is amongst the largest aluminium foil rollers in Europe, and it is fully appreciated that, besides having first-class production facilities and expert technicians, effective quality control and laboratory research are essential for success. Thus, the company has followed a plan of steady development in its laboratory organisation, which is now taken a stage further in the opening of the new wing. Under Dr. T. H. Angel, the combined ability and experience of specialised technologists is brought to bear on problems of research and quality control. Whereas before the war the staff consisted of three qualified technologists and one assistant, there are today nine technologists and eleven assistants, together with a staff of twelve working round the clock on production quality control in the inspection laboratory. Every encouragement is given to junior members of the staff to pursue a course of study leading to a degree or other qualification, because the company believes that a high academic standard, combined with a sound practical production knowledge, is essential for the necessary close co-operation between laboratory, factory and customer. This insistence on knowledge and experience has proved to be of paramount importance to Venesta in countering rising production costs and maintaining a consistently high quality of aluminium foil. Moreover, laboratory research has provided varieties of foil and foil laminates for an ever increasing number of end uses, and today the Venesta Coatings Manual lists more than 500 different specifications of foil which have been developed over the years.

The original building, which housed seven laboratories, a dark room, a tropical room, a balance room and offices, occupied a floor space of 2,700 sq. ft. This has now been increased to 4,335 sq. ft., by the addition of five new laboratories built on the first floor over existing storage premises. The new laboratories have been designed by the Venesta laboratory staff and are so constructed that the internal partitioning walls can be removed if necessary, so that the size and shape of the laboratories can be changed to cope with special forms of research or unusual experiments. Reference has already been made to the importance of co-operation between laboratory, factory and customer, as only in this way can the laboratory fulfil its proper functions, which are :—

(1) Development of new and improved materials and techniques in conjunction with the company's engineers.

(2) Co-operation with the production department by : (*a*) testing of raw materials to establish their quality ; and (*b*) operating a 24 hours a day inspection control, which not only ensures a consistently high quality of foil, but also diagnoses and rectifies any reduction in quality.

(3) Liaison with the firm's representatives and customers in dealing with difficulties that may arise in the handling and use of foil.

As Venesta foil is produced for a wide variety of end uses, ranging from milk capping strip and wraps for dairy products to confectionery and ice cream wraps, foil for electrical purposes, foil for packing pharmaceutical products, etc., a considerable amount of development work and testing is necessary to produce an ideal foil or foil laminate for each specific purpose, and to maintain its quality in production. Because the company produces material ranging in thickness from 0·005 mm. to 0·2 mm., and used for a variety of purposes, a number of the tests applied to it are peculiar to this industry. Reference will be made to these, and more usual tests, in the following notes.

Laboratory Tests

Chemical Analysis.—Because composition influences both fabrication and properties, aluminium foil is rolled from metal bought to purity specifications laid down by B.S. 1470. Incoming material is checked for its iron, silicon and copper contents, with an additional check for manganese in the case of special alloys which may be used.

Grain Structure.—Only aluminium having a fine grain structure is suitable for rolling to the thinner gauges of foil. To check the grain size, a sample of the material is cleaned with metal polish and electrolytically polished in an alcoholic solution of perchloric acid at a current density of 0·5 amp/sq. cm., for one minute. The sample is then etched in 1% hydrofluoric acid at a current density of 0·05 amp/sq. cm., for 5–10 minutes. The grain structure is examined under the microscope using polarised light, which shows up the grains in different colours and enables their size to be ascertained.

Tensile Strength.—To ascertain the tensile strength of partially annealed aluminium foil, Goodbrand tensile testers are used. A strip of foil is gripped by two pairs of jaws which slowly exert a pull. As the load is applied to the foil, it is registered simultaneously on an indicator until the foil breaks under the load, leaving the indicator showing the breaking load.

Bursting Strength.—Paper/foil and film/foil laminates are already widely used in packaging. It is important to know the bursting strength of the papers, films and laminates, so that customers can be offered wraps strong enough for their purposes. For this purpose the Schopper-Dahlen bursting strength machine is used, in which a wrap under test is burst under air pressure.

Perforation Counting.—Pieces of foil are placed over an illuminated aperture of given size, the number of perforations visible is counted, and the figure converted to give the number of perforations per square metre. The number of perforations is highest in the very thinnest foils. The British Standard specification for cheese foil does not allow more than 700 perforations per square metre in 0·012 mm. foil. Venesta's average figure is approximately 10% of the figure permitted. In fact, the Company has reduced the number of perforations in Venesta foil by more than 60% in the past five years.

Tropical Service Testing.—A special room is set aside for testing foil and foil laminates in tropical and humid conditions. The room is kept at a constant temperature of 90° F. and a relative humidity of approximately 90%. Corrosion of foil and of laminates under tropical conditions can be studied and the protection afforded by foil wrappings determined.

pH of Paper.—Acidity, which is not uncommon in paper, is liable to cause corrosion in paper foil laminates. To measure the *p*H of paper extract, the paper is first boiled in distilled water to dissolve any acidic or alkaline constituents. A pair of electrodes—connected to the *p*H meter—is then immersed in the extract and a reading of between 0 and 14 is given on the dial. For a paper to be safe for lamminating to foil its *p*H reading should lie above 5. Alkaline papers are unusual, but papers bearing a *p*H above 8 would be put through searching corrosion tests in the tropical room before use in a laminate.

Experimental Coating.—Experiments into coating and lacquering are carried out in the coating laboratory. With the aid of a completely new experimental coating machine, designed and built by Venesta engineers, it is hoped to develop new and better coatings for aluminium foil.

High Frequency Flaw Detector.—Coated aluminium foil of medium or heavy gauge is press-formed into dishes which are now widely used for packaging a variety of foodstuffs. Here it is necessary to determine whether the forming operation has damaged the coating and left flaws through which food acids could reach the aluminium. Small dishes are therefore made in the laboratory by dropping a heavy weight on to foil held in a die. The dish so formed is then filled with an electrically-conductive liquid. The coating acts as an insulator, and when an electrode, which is part of an electrical circuit connected with the dish, is dipped into the liquid, current passes between the electrode and any part of the metal of the dish which is uncoated, thus showing up any flaw in the coating. H.F. alternating current is used to avoid interference by deposition of metal or polarisation. The conductivity of the coating on the test dish is compared with a pre-determined standard. Low conductance indicates satisfactory coating.

Viscosity of Liquids.—It is important to know the viscosity of liquids such as inks, gums, and lacquers, used in foil production, as viscosity can, for example, affect coating weights. The laboratory uses a Ferranti viscometer for determining this property. This instrument comprises a constant speed motor which drives a hollow cylinder immersed in the solution being tested. Inside the cylinder is a second cylinder on a spindle connected to the dial on the top of the instrument. Rotation of the outer cylinder causes the solution to move and imparts " drag " to the inner cylinder which registers on a dial calibrated to record the viscosity of the solution.

Heat-Sealing.—A Funditor heat-sealer is used for testing the ability of coated foil to heat-seal at a certain temperature. This device consists of two jaws which can be electrically heated to a required temperature, and brought into contact by depressing a lever. Two pieces of heat-seal coated foil are placed between the jaws, and the lever depressed, sealing the contacting surfaces.

Water in Solvents.—Solvents used as vehicles for coating and printing aluminium foil are very costly, and are therefore recovered in an active carbon solvent recovery plant. In this recovery process, a certain amount of water may be included with the solvents, and to determine the amount the Karl Fischer apparatus is used. This comprises two burettes, one holding Fischer reagent and the other a standard water solution in methyl alcohol. The end point of the titration is indicated by a galvanometer.

Proving Inks and Lacquers.—One department of the laboratory specialises in formulating and testing inks and lacquers. For this purpose a miniature printing and lacquering machine is used to print or coat reels of foil. This department is also concerned with shade-matching to customer's samples. Shade-matching is a highly skilled business, and it is estimated that an operator, by practice, will become " reasonably proficient " after about five years' experience. Owing to the reflection through a transparent coating or print, spectrophotometric methods of matching and recording transparent

colours on aluminium foil have been found far less sensitive than the human eye, and shade matching on foil still depends on human proficiency.

Soxhlet Process.—Insoluble impurities in inks and dyes could emboss the foil and so cause a pimply appearance. To determine the amount of insoluble matter in dyes, the Soxhlet process of continuous extraction is used. A weighed quantity of the substance involved is placed in a container fitted with a siphon. A small amount of solvent is evaporated in a boiler and the vapours carried to a condenser. The condensate drops on to the substance to be extracted and the container slowly fills until the liquid level reaches siphoning point, when siphoning back to the boiler takes place. After a number of siphonings only insoluble matter is left. This can be dried and weighed, and its amount stated as a percentage of the original sample.

View of the inspection laboratory. The balances are being used for checking coatings, and the inspectors in the foreground are preparing foil samples for acid testing.

Inspection

Besides the main laboratories, an inspection laboratory is maintained in the factory itself, the purpose of which is specifically to ensure that every individual reel of foil is produced to a consistently high standard. Thus, a sample from every spool of coated foil produced by Venesta goes immediately to the inspection laboratory and is subjected to various tests, laid out under the manual number or specification for the particular customer. It is not possible to provide details of all the tests conducted, but the following give an indication of the work involved.

Coating Weight.—A sample of certain size is weighed accurately, cleaned of coating and re-weighed. From the difference in the two weights, the weight of the coating may be accurately calculated. The usual size of the foil sample used is 100 sq. cm., though this may vary according to the actual job. Correct coating weight is essential where foil requires protection.

Bleeding.—To ensure that inks and lacquers do not "bleed" in the presence of water or of oils or fats (particularly necessary in milk bottle capping strip) coloured foil samples are subjected to a "bleeding test." Samples are laid with the design (*a*) in contact with wet filter paper, and (*b*) in contact with filter paper impregnated with a vegetable oil, and the assemblies placed between sheets of glass. After lapse of the time specified for the test, the filter paper is examined and the amount of "bleeding" assessed.

Odour.—Solvents used in coating foil have a pungent odour, and it is important that this should not be present when the foil is despatched. Foil is laid on to a hot metal block and the inspector smells it to ensure that solvents are absent.

Continuity of Coating.—The following tests dealing with cheese wrapping foil are typical of the acid tests applied to check the continuity of the coating on foil.

(*i*) *Aluminium Foil.*—Strips of cheese-foil are left, coated side down, for half an hour on the surface of a solution containing 27 g. copper sulphate and 135 ml. hydrochloric acid, made up to 2,700 ml. with tap water. On removal from the bath, the coated surface should show no sign of reaction.

(*ii*) *Tin Foil.*—Strips of cheese foil are left, coated side down, on the surface of a bath of dilute nitric acid. Any faults in coating reveal themselves as black spots, where the nitric acid has attacked the metal.

Angle of Slip.—Some foil carries a slight coating of lubricant to assist its smooth passage through wrapping machines. To check that this coating has been correctly applied, a sample of the foil is laid on a sheet of glass and a slider placed on the foil. The glass is tilted until the foil slides. From the angle at which the glass is tilted, it is possible to determine whether the foil is lubricated to the required standard.

Moisture Content of Paper.—The use of water-gums for laminating foil to paper means that moisture must be extracted from foil/paper laminates, otherwise corrosion may occur. To determine the moisture present in paper in laminates, a sample is weighed, dried in a constant-temperature oven and re-weighed. From the difference in weight the moisture content of the paper can be calculated.

Bitumen/Paper Test.—A sample of hot bitumen is dropped on to paper which is intended for use in foil/paper/bitumen laminates. The paper must be capable of withstanding penetration by the hot bitumen.

Technical Service

To understand fully the functions of the laboratory, it is interesting to follow the case-history of an enquiry received for a specification not already formulated by Venesta. The enquiry is first sent to the technical enquiry committee, consisting of the heads of the laboratory, production and sales. The committee then decides the priority of the enquiry in the light of other work in hand, and which department is to deal with it.

This is frequently the laboratory. When the enquiry goes to the laboratory, the laboratory staff consider how to meet the customer's requirements and, as a preliminary move, a member of the laboratory staff often visits the customer to determine precisely what is required.

Experimental work is then carried out in the laboratory to arrive at a probable specification.

Next a tentative specification is drawn up and an experimental order issued to the production department. A member of the laboratory staff observes the experimental production run and studies the report of the production supervisor. Once all production problems are solved, the samples are checked against specification and the sample delivered to the customer.

If the customer reports favourably, the specification receives a manual number, which will ensure that all future quotations on the specification will be manufactured in exactly the same way as the original. If, however, the customer reports unfavourably, his comments are considered, where possible with a report of the Venesta technical representative, and the specification modified in the light of this experience.

Personal contact with customers is essential if difficulties are to be resolved speedily. For example, a Continental customer reported that heat-seal coated foil was "sticky." Assuming there had been an error in the formulation of the heat-seal coating, it was reformulated and a further batch supplied. The same complaint was made again by the customer. Consequently, Dr. Angel flew to visit the customer, and found that the method of using the foil was different from established British techniques. In fact, the problem arose because of friction between the coating and certain working parts of the machine.

This is merely one instance of the laboratory service given to customers—a service not merely designed to establish the quality of the foil, but to ensure that the foil laminate is the most suitable for the specific purpose for which it is actually used.

Australian Foil Mill

FOLLOWING talks in London, Aluminium, Ltd., of Canada, The British Aluminium Co., Ltd., and Venesta, Ltd., announce their intention of establishing in Sydney, Australia, an aluminium foil-rolling mill embodying the latest equipment and technique. Aluminium, Ltd., and The British Aluminium Co., Ltd., are already partners in the Australian Aluminium Co., Pty., Ltd., of Sydney, producers of aluminium sheet, extrusions and related semi-fabricated products. Venesta, Ltd., one of the largest manufacturers of aluminium foil in the British Isles, produces all types of foil, ranging from plain foil for cigarette and cheese wrapping and coloured designs for chocolate and confectionery to the special types of foil used in the electrical industry. The Company have long been suppliers of aluminium foil to the Australian market.

The three companies will each have one-third ownership of the new venture. The Australian Aluminium Co., Pty., Ltd., will supply the new enterprise with its basic raw material, aluminium foil stock. Production, which will include heavy and light gauge foil as well as decorated and laminated foil will be sold mainly on the Australian market. The establishment of the new plant will mark another step in Australia's progress towards industrialisation—at present most of the aluminium foil used in the country is imported from Britain.

Birlec Units for Melting Special Steels

BIRLEC, LTD., have received an order from Rolls Royce, Ltd., for four Birlec Detroit furnaces, model 1C, to be used for the melting of special alloy steels. This is the second order of this type to be placed with Birlec recently; H. & F. Precise Castings, Ltd., Derby, now have a total of seven 1C furnaces engaged in the manufacture of turbine blades for the Ministry of Supply, working to extremely fine limits on special alloy steels.

This indirect arc melting furnace has a capacity of 10 lb. of molten steel or iron in a melting chamber which takes the form of a refractory crucible, and is a self contained unit measuring 4 ft. in height, 4 ft. in width and 4 ft. from front to rear. With the lining in good condition and the furnace operating at full power, 10 lb. of steel should be melted in 15 minutes, while the same amounts of phosphor bronze and 70/30 brass take 10 minutes and 8–10 minutes respectively.

Melting a ton of iron or steel in this furnace uses approximately 700 kWh. of power when starting with a hot lining. Rocking of the IC furnace is by hand. As the unit is so small, with a melting time of not more than 15 minutes, automatic rocking is expensive and unnecessary, and the furnace is so balanced that it can be rocked by hand with very little effort.

Roll Makers Silver Jubilee

THE Roll Division of Armstrong Whitworth (Metal Industries), Ltd., recently celebrated its 25th Anniversary with a Silver Jubilee Dinner at Newcastle upon Tyne. When the late Major T. G. Bird decided to enter the complicated and highly-competitive roll making industry in 132, he joined up with an established roll making concern, namely, The Blaw Knox Co., of Pittsburgh. For 25 years this association has continued to the mutual advantage of the two companies. The value of rolls delivered from the works has grown steadily since 1932, the record figure for 1956 exceeding £1 million. These rolls were delivered to the main steel works in Great Britain, Canada, Australia, South Africa, India and the Continent of Europe.

Nuclear Contracts for TI

CONTRACTS for over 200 miles of tubing, mainly of austenitic stainless steel, have been received by the Tube Investments subsidiary, Accles & Pollock, Ltd., from the A.E.I.—John Thompson Nuclear Energy Co., Ltd., and the G.E.C.—Simon-Carves Atomic Energy Group, who are building the nuclear power stations in Gloucestershire and on the Ayrshire coast. Each reactor will be equipped with "burst slug" detection gear which enables faulty fuel elements to be detected immediately, and removed, so preventing contamination of the reactor and heat exchangers. This detection is effected by taking regular samples of gas from inside the reactors, and the tubes ordered are used for conveying these gas samples to the monitoring instruments. Some of the tubes will be supplied in straight lengths and others manipulated and part fabricated.

College Library Wants Catalogues

MANUFACTURERS are invited to send catalogues to the Library of the College of Technology, Gosta Green, Birmingham, 4.

The Development of the Iodide Process of Refining Titanium and Zirconium

By R. A. J. Shelton, B.Sc.

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The van Arkel or iodide process for the refining of titanium and zirconium owes much to workers in the incandescent lamp field. Following a description of van Arkel's apparatus, the author traces the hot filament technique from the carbon filament lamp, through the metal filament lamp and the preparation of single crystals of metals such as tungsten, to its application by van Arkel to the purification of titanium and zirconium by the dissociation of the tetraiodides.

ZIRCONIUM and titanium—first prepared by Berzelius in 1824 and 1825, by Troost and Phipson in 1865, and by Moissan in 1893 and 1895—were for a long time considered to be hard and brittle metals,[1] and this description persisted in the text-books up to the last decade or so. Hunter[2] in 1910 had prepared titanium by the reduction of its tetrachloride with sodium in a metal bomb and reported that small pieces of the metal selected from the reaction residue were malleable, but it was van Arkel and his colleagues at Philips, Eindhoven, who, from about 1923, prepared zirconium and titanium (and hafnium and thorium) in a lustrous crystalline form and convincingly demonstrated the ductility and relative softness of these metals. This was achieved by means of the iodide process, alternatively named the van Arkel process, and also known, particularly in the United States, as the hot-wire process. It is a refining process, the raw material for which may be obtained by methods similar to those of the early workers, namely the sodium reduction of the tetrachlorides of these metals, or the sodium reduction of potassium fluorzirconate and potassium fluortitanate, both methods involving the use of a steel or cast iron bomb; or by the magnesium reduction of the tetrachlorides, as in Kroll's process.[3]

The refining depends on the continuous formation and thermal decomposition of volatile iodides :—

$$TiI_4 \underset{200^\circ\,C.}{\overset{1,200^\circ\,C.}{\rightleftharpoons}} Ti + 2I_2$$

$$ZrI_4 \underset{300^\circ\,C.}{\overset{1,500^\circ\,C.}{\rightleftharpoons}} Zr + 2I_2$$

and bears a formal resemblance to the nickel carbonyl process :—

$$Ni(CO)_4 \underset{40^\circ\,C.}{\overset{180^\circ\,C.}{\rightleftharpoons}} Ni + 4CO$$

The dissociation temperatures are much greater in the iodide processes, and an electrically heated filament serves as the decomposition site. These tetraiodides, structurally similar to carbon tetrachloride, are readily hydrolysed and fume on exposure to air. When warmed in air they are decomposed to the dioxide and iodine. These properties and the now well-known solvent capacity of these metals for oxygen, nitrogen and hydrogen, coupled with their reactivity when hot towards most other gases, demand the use of vacuum techniques in the refining process, rather than a flow method such as is used in the carbonyl process, in which the nickel carbonyl is carried with excess carbon monoxide and hydrogen into the decomposition chamber.

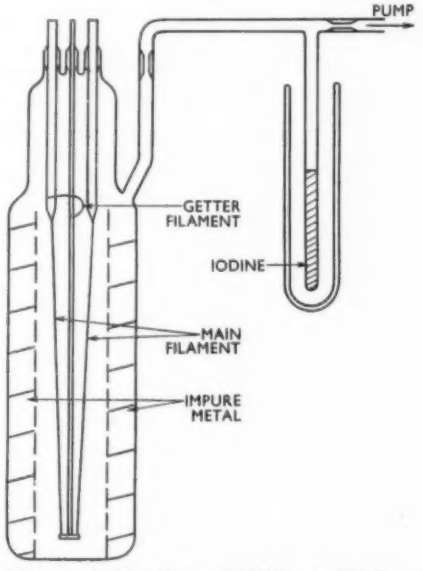

Fig. 1.—Iodide decomposition apparatus.

The van Arkel Apparatus

The apparatus[4] for the iodide process as developed in the Philips' laboratories is shown diagrammatically in Fig. 1. The glass reaction bulb contains a side arm for connection to the pumping system, with a limb to contain the iodine, and the raw material is placed between the inner wall of the bulb and a cylindrical fine mesh molybdenum grid. The filament, thin tungsten wire in the form of a hairpin, is suspended from two tungsten electrodes sealed into a glass head, which carries in addition a thinner tungsten rod to support the filament. A getter filament is included by attaching a smaller length of the thin tungsten wire between the support rod and one of the electrodes. This assembly is sealed to the neck of the reaction bulb and it is here that the apparatus is opened at the end of a preparation. The

Fig. 2.—Iodide zirconium. × 7

reaction bulb is supported in an oven and electrical connections made to the electrodes ; with iodine in the side limb surrounded by a suitable coolant, the pumping line is completed and the apparatus is evacuated, outgassed at about 500° C., and then sealed from the pump. At oven temperatures of about 200° C. for titanium and 300° C. for zirconium, the iodine is sublimed into the reaction bulb where it reacts with the impure metal, filling the bulb with the deep red crimson tinged vapour of titanium tetraiodide, or the greenish yellow vapour of the zirconium compound.

At this stage the iodine reservoir is sealed from the bulb, and with these ambient temperatures maintained, the getter filament is heated electrically to about 1,200° C. for titanium and 1,500° C. for zirconium. Decomposition of the tetraiodide takes place on the getter filament ; metal is deposited there, and the iodine set free returns to the bulk vapour phase and combines with the excess of the raw material to maintain the iodide concentration. In this way the getter filament increases in diameter as indicated by the increase in current in the filament circuit. During this time residual atmospheric gases in the apparatus and those rapidly desorbed from the raw material by the iodine-iodide atmosphere are removed by the deposited metal on the getter filament, by dissolving in it or by reacting with it.

After a suitable time the getter filament is dispensed with and the hairpin filament is heated to its appropriate temperature. As with the getter filament, this increases in size, the current through it increasing from about 1 amp. to 100 amp. in a few hours, when it has a diameter of about 3 mm. In this way a rod of the metal is built up, consisting of a series of large crystals with highly reflective facets, free from many of the impurities in the raw material. Fig. 2 shows a piece of zirconium prepared by this method. It is alternatively described as " van Arkel " or " iodide " metal, while in the United States it is more commonly referred to as " crystal bar."

Earlier Use of Hot Filament Technique

There are many instances prior to the work of van Arkel in which an electrically heated filament was used to carry out the thermal decomposition of volatile compounds. It would appear that the use of the hot filament technique has been associated with three main objectives :—

(1) The preparation of filaments for use in the incandescent lamp.

(2) The preparation of metallic single crystals.

(3) The preparation of pure metals of the titanium group.

Each objective achieved major prominence during three consecutive and fairly distinct periods of time, and the historical development of van Arkel's iodide process can be seen in the successive modification of the early techniques. The earlier work generally employed flow methods in dealing with the volatile compounds, and in tracing the evolution of the iodide process, one is made acutely aware of the development of techniques in this branch of experimental chemical metallurgy. The elegant work of van Arkel which crowned this epoch could only have taken place in a research laboratory of the electric lamp industry. It drew on the acquired skills of glass-working and vacuum technology, and nonchalantly used tungsten and molybdenum as incidental constructional materials. Only in such establishments was there to be found such sophistication of approach and wealth of material resources.

The Preparation of Filaments for Incandescent Lamps

By its very nature the hot filament technique was intimately connected with the electric lamp industry. The terms employed and the materials and equipment used were common to both, and the history of the industry[5-8] provides the background of the iodide process. With the twentieth century in sight, electric lighting popularly meant illumination by the carbon arc, the Gaiety Theatre, London, being among the most spectacular of public places lighted by this means, but from 1802, when Davy at the Royal Institution raised a strip of platinum to incandescence by placing it across a battery, there were many attempts to use such a luminous source. These variously used carbon rods and platinum wires in the form of spirals and loops, with and without envelopes, and running in air, nitrogen or a partial vacuum. They were frustrated for the most part by the inability of the existing mechanical pumps to produce a suitable vacuum, and by the unsuitability of the available sources of electrical energy.

The idea of the incandescent lamp as an electrically heated wire in a vacuum envelope, was in advance of the resources of the contemporary technology. Du Moncel, in his book " Electric Lighting," leaves one with the impression that the future was to be illuminated by the arc-lamp, he being sceptical of the reports of Edison's activities in the field of the incandescent filament lamp. (Edison had just added to the range of platinum filament lamps and had announced the future appearance of a carbon filament lamp). This scepticism seems to have been in the nature of a reaction to a decline in prices of gas shares on the stock market, but even with some knowledge of Swan's work, du Moncel seemed convinced that the solution to the problem of the " divisibility of electric light " did not lie with the incandescent lamp[9]. However, arc-lighting, with its undesirable brilliance, instability, and large current consumption, was not suitable for domestic use, and by about 1880, the carbon filament lamp was established.

Handicapped as they were, the early investigators

were nevertheless able to show that platinum was not an entirely satisfactory material from which to construct incandescent lamp filaments. Even with the improved vacuum pumps available, it was necessary to operate at relatively low filament temperatures to avoid evaporation of the platinum and its blackening of the envelope. This gave such a low luminous efficiency that platinum was not hereafter seriously considered, and attention was turned to carbon as an alternative refractory and conducting material.

Carbon Filament Lamps

From 1860, when he used a strip of carbonised paper mounted in a bell jar, Swan moved assuredly towards the achievement of his carbon filament lamps, and in 1879, he demonstrated them at a meeting of the Newcastle Chemical Society. Starting later than Swan, Edison, with his characteristic ingenuity and thoroughness in experiment, independently produced a similar lamp and applied for the patent rights in 1880. There followed the promise of a struggle over the assignment of prior invention, but a conciliation was effected resulting in the Edison-Swan United Electric Lighting Company.

Swan and Edison were able to pursue their work with two great advantages over their predecessors in the availability to them of improved dynamos and the mercury vacuum pump. The former ensured the commercial feasibility of widespread electric lighting following the successful manufacture of lamps, while Sprengel's invention of 1865, the capabilities of which had ably been demonstrated by Crookes in the construction of his radiometer, provided the key to successful manufacture. The problem was clear and essentially reduced to that of preparing suitable filaments. It was realized that higher resistances than those formerly employed were necessary, and with the material now required to be in a thinner form, the word filament became particularly associated with the electric lamp. All manner of natural fibres and cellulose materials were used, these being carbonised by baking in graphite. Edison inclined towards the use of natural materials, sending to Japan for a particular species of bamboo, while Swan preferred to prepare cellulose filaments by parchmentising cotton thread in sulphuric acid, and later by extruding fine threads of a viscous solution of cotton in aqueous zinc chloride.

At this stage came advances in the allied manipulations. Vacuum techniques were developed appropriate to the high vacuum pumps now available, which differed only slightly from those used today. The bulb was outgassed by flaming during evacuation ; carbonisation products in the filament were removed by heating them above their operating temperature, again under the pump ; and the use of a getter—in the first instance, red phosphorus—was introduced. The original platinum current leads were reduced in length to give just sufficient metal for sealing into the glass, and welded to nickel to complete the internal and external conductors. This platinum seal was later replaced by a nickel-iron alloy, copper plated, sheathed to brass and then to copper, the whole having the same coefficient of linear expansion as the glass. The difficult task of attaching the fragile carbon filament to the current leads was carried out by an ingenious method.[10] The hollow ends of the nickel alloy wires received the filament and the assembly was heated electrically under a liquid hydrocarbon. The carbon deposited by the decomposition of the hydrocarbon cemented the filament to the wires.

One of the unsatisfactory features of the earlier carbon filaments was their lack of uniformity in diameter, resulting in a non-uniform source of illumination. This was overcome by subjecting the filaments to a treatment known as flashing, which is probably the earliest instance of a successful application of the hot filament technique. This process, independently patented by Sawyer and Man and by Lane-Fox in 1879, depends on the thermal decomposition of a hydrocarbon vapour at the surface of the electrically heated carbon filament. Carbon is preferentially deposited at the thinner and hotter regions of the filament so that it eventually assumes a uniformity in diameter and in brightness. The apparatus for this process consisted of a bell-jar with a rubber ring gasket standing on a steel plate, carrying a three-way stopcock connected to the pump, the hydrocarbon reservoir, and the atmosphere. Metal clamps mounted in the bell jar held the filament and carried the current to it. It can be imagined as similar to a present day small scale metal evaporation unit. A similar method was used by Cruto to prepare rather than improve a carbon filament in which ethylene was decomposed on thin platinum wires, and Maxim's carbon filament lamp of about this time operated in a hydrocarbon atmosphere so that irregularities in resistance at various points were equalised *in situ*.

Metal Filament Lamps

Although a time of intense patent activity relating to the improvement of lamp manufacturing processes, the period 1885–1900 saw no fundamental improvement in the lamp itself. They were without rival, yet the filament had to be operated greatly below maximum efficiency to avoid evaporation of carbon from it. Further improvement could come only from new filament materials, and with European manufacturers anxious to be free from the patent restrictions, attention was turned towards the high melting point metals, of which tungsten was considered to be the most suitable. The Westinghouse Company in 1883 had employed Lodyguine (who in Russia had been associated with carbon arc and incandescent carbon rod lamps) to investigate the possibility of preparing and using metal filaments. He attempted to coat platinum wires and carbon filaments with osmium, tungsten, molybdenum and chromium, and a hot filament technique seems to have been used for tungsten at least,[11] but no details for the other metals appear to have survived. The work probably had little sustaining impetus, due most likely to the fact that it was carried out with the image of Edison and the carbon filament lamp dominating the background.

Osmium

With the timely invention by Moissan of the electric arc furnace as an aid in dealing with these metals, the experimenters were soon dismayed by their apparent intractability. It was now that the hot filament technique came to the fore as a preparative method, a volatile compound of the metal replacing the hydrocarbon of the flashing process. Welsbach, turning his attention from gas to electric lighting, prepared osmium filaments by the thermal decomposition of osmium tetroxide vapour on heated platinum wires. In a development of this method the volatile oxide was decomposed on a carbon

filament, the carbon being eliminated as carbon monoxide, leaving a filament of pure osmium. As a result of this work osmium was shown to be a suitable filament material, but that this method of preparation was proposed as a commercial process would seem to be due to the times, in which patent application was a necessary consequence of any work connected with the incandescent lamp.

The hot filament technique was ideally suited to investigational work of this kind ; that is, for establishing the suitability of particular metals for use as filaments : fortuitously, the metals under consideration possessed the necessary volatile compounds. The method required the use of small quantities of materials only, the product was obtained in the desired form, and the successful deposition of the metal gave in itself the positive information required. Welsbach then introduced a process for manufacturing osmium filaments more suited to commercial production. The metal powder, mixed with a cellulose binder, was forced through a die on to a tray moving in such a fashion that the extruded mixture was received as a series of loops. After careful drying they were sintered *in vacuo*. These filaments were very fragile, porous and contained much carbon, so that after mounting to the current leads and insertion in a lamp, much care was necessary in handling. These lamps, which could be used only in one position, had a very uncertain life, but even so they presented the first challenge to the carbon filament lamp and enjoyed some success.

In Welsbach's second process the filaments were " put together " in the sense that they were only partially sintered and very porous, while the requirement was coherent material, which pointed to wire drawing as the most likely way of providing the metal in a suitable form. This had previously been attempted without success, and such was the position when von Bolton, in 1901, began an investigation of vanadium, niobium and tantalum for the Siemens Halske Company.

Tantalum

After a preliminary survey, tantalum, with the highest melting point of the metals in this group, and thus possessing the major claim for filament suitability, received most attention. Von Bolton recognised that the metal produced in the Moissan furnace consisted largely of carbide, and he considered that the purity of the metal was the factor controlling its ability to be drawn to wire. He prepared massive ductile tantalum by arc melting *in vacuo* the metal powder obtained by the alkali metal reduction of potassium fluortantalate. This was successfully drawn into wire and, with the " spider " arrangement to accommodate the now much longer length of thinner filament, the first tantalum lamps became commercially available in 1903. There was, however, still an awareness that tungsten was a better material for filaments ; its higher melting point would permit of greater luminous efficiencies, and the tantalum lamp served to intensify the efforts to obtain tungsten filaments.

Tungsten

The work on tantalum could not be repeated using tungsten, in spite of the relative ease in obtaining pure tungsten powder, and again recourse was made to the hot filament process, this time by Just and Hanaman, who used the same pattern of approach as Welsbach. Tungsten oxychlorides were entrained by hydrogen and passed over a heated carbon filament ; the metal was deposited on the filament, oxygen being removed as carbon monoxide and chlorine as hydrogen chloride.

$$WOCl_4 + 2H_2 + C \longrightarrow W + CO + 4HCl$$

$$WO_2Cl_2 + H_2 + 2C \longrightarrow W + 2CO + 2HCl$$

On the isolation of the oxychloride from the reaction system, further heating of the filament converted tungsten to tungsten carbide, which on still further heating in a hydrogen-water vapour mixture lost carbon as carbon monoxide (described at the time as " sweating out the carbon "[12]), leaving a filament of tungsten in tubular form. A German patent was granted in 1904, and an English patent in 1905, the process having been modified by the use of tungsten hexachloride instead of the oxychloride. Again, one cannot imagine this as a commercial proposition, but it served to confirm the suitability of tungsten as a filament material.

At the same time Just and Hanaman patented a process for squirting a paste of tungsten powder and an organic binder analogous to Welshbach's process for osmium. In this case, sintering in a hydrogen-water vapour atmosphere after drying gave a more coherent product than obtained with osmium, and the possibilities of the commercial preparation of the tungsten lamp became real. Other squirting processes were proposed involving tungsten amalgams, tungsten-osmium mixtures and colloidal tungsten without organic binder. With the acquisition of the Just and Hanaman patents by the newly formed General Electric Company, the centre of filament activity moved to America, and in this Company's laboratories Coolidge studied the sintering of tungsten. He demonstrated its ductility at elevated temperatures and, relating this to the grain-size of the metal, devised hot-swaging treatments so that tungsten was obtained sufficiently ductile at room temperature to permit cold drawing to wire.

Mention must be made of the Helion lamp as a late attempt to use an alternative filament material prepared by the hot filament technique. The flashing process was used to deposit silicon from a volatile silicon compound on to a carbon filament raised to incandescence, and most likely silicon tetrachloride was used to give silicon carbide as the final product. When the Coolidge processes[13] were patented in 1909, the real success of the tungsten lamp was assured, and the industry had apparently no further need of the hot filament technique. In this time it had been established as a valuable preparative method embodying small scale high temperature work at a localised reaction zone, capable of close temperature control, and free from general refractory contamination, that arising from the starting filament being no serious disadvantage.

Other Heated Filament Techniques

Further examples of the use of the technique from about this time serve to show its application to activities other than filament preparation. Von Pirani,[14] studying solutions of hydrogen in tantalum—an offshoot of von Bolton's work—prepared deposits of tantalum containing dissolved hydrogen on platinum wires by passing hydrogen/tantalum pentachloride mixtures over the hot filament. Weintraub[15] prepared boron in a modification of the technique, in which the " filament " was an

electrically heated graphite tube through which a mixture of boron trichloride vapour and hydrogen was passed. The product was considered to be quite pure and was used for the determination of various electrical properties.

Pring and Fielding[16] carried out experiments in which a range of volatile chlorides—BCl_3, $AlCl_3$, CCl_4, $SiCl_4$, $TiCl_4$, VCl_4, $MoCl_4$, $MoCl_5$, WCl_6 and $CrOCl_2$—were decomposed on an electrically heated carbon rod, in the presence of hydrogen. They found that in many cases hydrogen was not necessary to bring about the decomposition, and noted the temperatures at which carbides were formed. In comparing the apparatus used in this work with von Pirani's, the influence of the lamp industry is evident. Von Pirani working at the Siemens Halske Glühlampenfabriken, Charlottenburg, used glass to metal seals; Pring and Fielding in the University Electrochemistry Laboratories, Manchester, used a carbon rod sealed into the reaction vessel with wax.

The Preparation of Single Crystals

The period embracing the last years of the nineteenth century and the first few years of the twentieth century was a happy one for patent applicants in the field of the incandescent lamp. Old processes were re-introduced and new processes were improved; but it was by serious and systematic endeavour that Coolidge gained the prize of ductile tungsten for the General Electric Company. Many companies had employed scientists of established reputation to work for relatively short periods on particular problems, but the industry was not generally attuned to the idea of the fundamental laboratory. In 1900, the General Electric Company had persuaded Dr. Whitney of the Massachusetts Institute of Technology to act as director of their long term work. This he did for three years while retaining his post at M.I.T., and subsequently he directed the laboratories in a full time capacity. In his history of this Company, Keating[17] tells how this shrewd judge of ability, having obtained the services of Coolidge, now recruited Langmuir to his staff. On being shown round the laboratories at Schenectady with the injunction to work on any topic which appealed to him, Langmuir's interest was aroused by a blackened lamp (caused by excessive evaporation of tungsten from the filament). The results of this interest were the gas-filled lamp, the filament now operating in an atmosphere of nitrogen to reduce the evaporation, and the coiled coil filament, introduced to overcome the problems posed by convection in the gas-filled lamp. In addition, Langmuir carried out a series of investigations on the pick-up of gases by heated tungsten filaments and added considerably to the knowledge of chemical kinetics and surface chemistry.

Later laboratory study of grain growth in tungsten filaments gave rise to thoriated tungsten, the addition of thoria restricting grain growth and preventing filament sag in operation, and by the early nineteen-twenties most aspects of the tungsten lamp had been investigated and were well understood. Meanwhile, the research laboratories of the electric lamp industry were making important contributions to the progress of science, and current interest in metallic single crystals gave rise to the preparation of large single crystals of tungsten. Appropriately, the hot filament technique was used and in this work, continuous deposition of the metal now took the place of flashing.

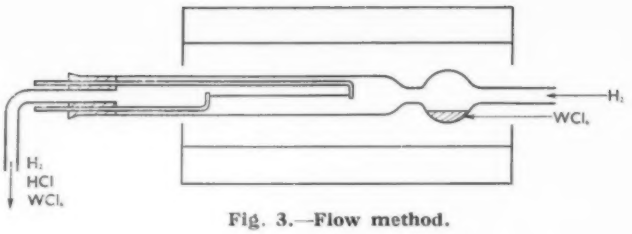

Fig. 3.—Flow method.

Thermal Decomposition of Tungsten Hexachloride

Koref,[11] at Osram, Berlin, carried out experiments to establish whether the use of a single crystal wire of tungsten as the filament had any influence on the structure of the deposited metal. He used essentially the same method as Just and Hanaman twenty years earlier, namely the thermal decomposition of tungsten hexachloride in the presence of hydrogen,

$$WCl_6 + 3H_2 \longrightarrow W + 6HCl$$

and Fig. 3 represents the apparatus he used. This work employed a flow method in which hydrogen was passed through the apparatus at slightly greater than atmospheric pressure and the tungsten hexachloride (m.p. 275° C., 6 b. 347° C.) was volatilised into the gas stream by heating the oven containing the hexachloride reservoir and filament chamber. With the filament at red heat, the deposition of tungsten took place, giving rise under these conditions to a porous, dendritic polycrystalline mass of metal. By lowering the partial pressure of tungsten hexachloride in the gas mixture and working with a reduced total pressure in the reaction chamber, excess reactants and gaseous hydrogen chloride being removed by pumping, Koref obtained a deposit on the filament in the form of a single crystal, the filament increasing in diameter from 0·05 mm. to 0·15 mm. in the space of 30–40 minutes. The optimum conditions for steady deposition as a single crystal were found to obtain with an ambient temperature of 110° C., a total pressure of 12 mm. Hg, and a filament temperature of 1,000° C. These single crystals were brittle but could be made ductile by heating, though not completely so.

Further work on this method was carried out by van Arkel[18] at Philips, Eindhoven, who required tungsten single crystals for the measurement of their lattice parameters. Considering that the hydrogen used for entraining and reducing the tungsten hexachloride was capable of being absorbed by the growing filament, and of introducing impurities to it, he sought to avoid its use by discarding the flow method, volatilising the hexachloride from a reservoir into the filament chamber and pumping off the chlorine set free by the filament reaction

$$WCl_6 \longrightarrow W + 3Cl_2$$

The apparatus, shown in Fig. 4*a*, which contains tungsten electrodes sealed into the glass vessel, bears some resemblance in form to the electric light bulb. In addition to confirming Koref's observation that the growth of a single crystal was favoured by a low pressure of tungsten hexachloride, van Arkel indicated that the rapid removal of chlorine was also a very important factor to the success of the deposition.

Sealed Bulb Technique

Langmuir, in the course of his extensive work on the pick-up of gases by hot filaments, had used a sealed bulb

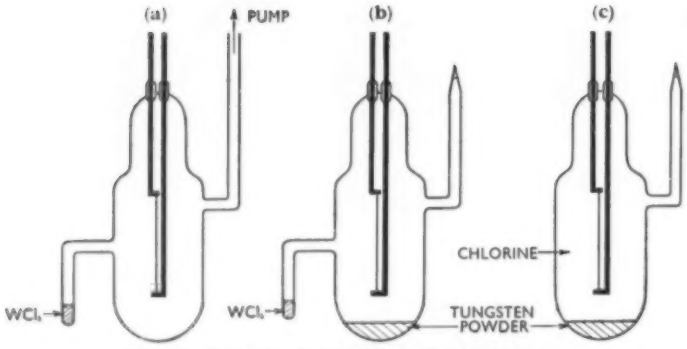

Fig. 4.—Genesis of the sealed bulb technique.

containing two tungsten filaments and a small pressure of chlorine.[19] When one of these filaments was heated to about 1,000° C., it increased in size at the expense of the other, and Langmuir concluded that transfer of tungsten took place due to the formation of tungsten hexachloride at the cold filament and its decomposition at the heated filament. This work was referred to by van Arkel in his paper, and he now used the phenomenon as a means of removing chlorine from the reaction vessel. In place of Langmuir's second cold filament, van Arkel used tungsten powder ; tungsten hexachloride was placed in a side-arm (see Fig. 4*b*) to allow the filament bulb to be degassed, after which the apparatus was sealed off. The hexachloride was sublimed into the filament bulb and the chlorine set free at the heated filament was rapidly removed by its reaction with the tungsten powder to give more hexachloride. In this way, continuous evacuation was made unnecessary, and a further step was to dispense with the initial addition of tungsten hexachloride, replacing it with chlorine after prior removal of air. After sealing off the apparatus and warming, the chlorine readily combined with the tungsten powder to give the hexachloride necessary to start the deposition, and the pressure of the volatile compound was maintained by its continuous formation from the chlorine set free in the filament reaction and the excess of metal powder. This apparatus, represented by Fig. 4*c*, no longer required the side arm for the hexachloride, and represented the final stage in the transition from the flow to the sealed-bulb method of operating the hot filament technique. Using single crystal tungsten wires as filaments, suitable crystals were obtained for the lattice parameter measurements.

Geiss and van Liempt[20], also of Philips, who were interested in metallic diffusion, used these methods to prepare single crystal specimens. Starting with a tungsten single crystal filament and decomposing firstly molybdenum pentachloride, and then tungsten hexachloride on the deposited molybdenum, they obtained a single crystal rod consisting of three concentric layers : tungsten, molybdenum, tungsten. Fischvoigt and Koref[21], used the flow method to investigate the deposition of molybdenum, tantalum, vanadium, chromium, iron, zirconium and titanium on single crystal tungsten filaments by the decomposition of their chlorides in the presence of hydrogen. Here they stated clearly the requisite properties of the metal whose deposition was required. These were : (*a*) the metal should possess a volatile chloride ; and (*b*) it should have a melting point greater than the decomposition temperature of the chloride.

They found that no deposit was obtained in the case of chromium because its chloride possessed insufficient volatility. Vanadium and iron were obtained as polycrystalline deposits, and the remaining metals were allegedly deposited as single crystals, but the optimum experimental conditions were not given. The authors suggested that a size factor rather than an isomorphous relationship between the metal of the filament and the deposited metal determined the growth of a single crystal, but this may have been forced on them by the results of their experiments with titanium and zirconium. An appraisal of the work with the prior knowledge of the allotropy of these two metals would probably lead to a reversal of this conclusion ; the application of the criterion of isomorphism might have led to the anticipation of their allotropy.

These applications underline the value of the hot filament technique as a preparative method, but the salient feature of this period is the emergence of van Arkel's sealed bulb technique, with its overall transfer of metal from the charge to the filament, hinging on Langmuir's historically important discovery.

The Preparation of Metals of the Titanium Group

Although the work on the preparation of single crystals has been cited as a successful application of the hot filament technique, it achieved its most spectacular success in the hands of van Arkel and de Boer. They used the method to prepare titanium, zirconium, hafnium and thorium, and though this was no greater achievement than the preparation of tungsten single crystals, the fact that these metals were now obtained for the first time in a coherent, ductile form added a brilliance to the elegance of the sealed bulb technique. The announcement[22] of the preparation of these metals in a pure form gave only an outline of the necessary experimental conditions for the deposition of zirconium, and no details at all for the other metals.

As the background to their use of the hot filament technique, van Arkel and de Boer reviewed their own unsuccessful attempts to prepare zirconium in a massive and ductile form. In this they show an awareness that oxygen was the cause of the brittleness of the metal. They came to the conclusion that only the hot filament technique was capable of giving a product free from contamination by oxygen, and they subjected the flow method to a thorough examination, passing zirconium tetrachloride and hydrogen over a heated tungsten filament. Their findings showed the flow method as an excellent preparative technique for zirconium carbide, nitride and oxide with the result that the work of Fischvoigt and Koref lost much of its significance. The deposit obtained on the filament was shown to consist of these compounds by Debye-Scherrer photographs, and their formation was attributed to impurities in the hydrogen.

With the use of carefully purified hydrogen no deposit was obtained at all, and van Arkel and de Boer suggested that the process by which a metal was deposited on a heated filament from a volatile compound was thermal

dissociation and not high temperature reduction, hydrogen serving to remove the chlorine set free in the dissociation. The high temperature necessary for the dissociation of zirconium tetrachloride could be achieved initially with a tungsten filament, but it was either greater than the melting point of zirconium or at a temperature at which its vapour pressure was greater than that in the dissociation reaction.

$$Zr\ Cl_4 \longrightarrow Zr + 2Cl_2$$

for the deposition of the metal to proceed satisfactorily. Consequently they argued that as iodides are generally less stable than the corresponding chlorides, zirconium tetraiodide might be dissociated at a suitably lower temperature, at which these contingencies did not arise. Furthermore, they observed that as hydrogen iodide is completely dissociated above 1,000° C. the use of hydrogen would be ineffective in removing iodine at the filament temperatures used in the process.

These premises led directly to the use of the sealed bulb method, with brittle zirconium and iodine replacing the tungsten powder and chlorine of the single crystal preparation. After evacuation and sealing off the bulb, zirconium tetraiodide was formed from the elements by heating the apparatus to 650° C., and with the thin tungsten filament (40μ diameter) heated to 2,600° C. by the passage of 0·5 amp, the reactions proceeded smoothly, zirconium being deposited on the filament which grew in size to about 3 mm. diameter after 2–3 hours and took a current of about 100 amp. The metal so obtained was undoubtedly the most massive piece of the purest zirconium so far prepared, and was described as "extraordinarily soft and ductile, similar to copper in these properties." Hafnium, titanium and thorium were prepared in like manner and were also found to be soft and ductile.

The use of the hot filament technique as a refining process for these metals had now been established, and the details for the preparation of zirconium, hafnium and titanium, together with some of their physical properties, were given between the years 1926–1939 in a series of papers[23-26] from the Eindhoven laboratory entitled "On the Preparation of Pure Metals of the Titanium Group by the Thermal Dissociation of their Iodides," under the authorship of de Boer and Fast. A contribution on the preparation of thorium did not appear. During this time, the Philips laboratories investigated the allotropy of these metals and demonstrated and determined the extensive solubility of oxygen and nitrogen in titanium and zirconium. In recognising the embrittling effect accompanying this solubility, the lie was finally given to the description *hard and brittle*. It is probably true to say that as a result of all of this work, the foundations were laid of the physical metallurgy of titanium and zirconium, and the way pointed for the use of inert gas and vacuum techniques in dealing with these metals at high temperatures.

During the nineteen thirties the hot filament technique was applied to the preparation of carbides and nitrides of the high melting point metals, and the preparation of most other metals which formed volatile compounds was attempted. These were desultory and sporadic attempts for the most part, neither matching the aesthetic appeal nor exciting the imagination as did the preparation of zirconium, hafnium and titanium. As with the earlier preparation of filaments, the iodide process could not be pictured as a commercial method. The only demand for the pure metals was for zirconium, as a getter in radio valves and as a surgical material, which could easily be satisfied by an occasional laboratory preparation. Consequently, the pure metals remained largely as laboratory exhibits, and they were apparently never prepared outside the Philips' laboratories. The later discovery of the low neutron absorption cross section of zirconium gave rise in the United States to a demand for the metal with the greatest possible purity for use as a constructional material in nuclear engineering projects. The iodide process ensured that this demand could be met, and iodide zirconium was used as the structural material of the submarine thermal reactor. Metal reaction vessels took the place of the glass bulb and quantities of metal of the order of 100 lb. were obtained from a single preparation. The new techniques[27] developed to achieve this were worthy of the process, which was still that of van Arkel and de Boer.

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Ceramic Tools Bibliography

SENSATIONAL claims have been made for ceramic tools which are said to be capable of cutting the hardest of metals. Manufacturers say that these tools can operate at higher cutting speeds than conventional steel or carbide tools and yet do not require cooling; they will cut almost anything and give a better finish; they are versatile and, generally speaking, are cheaper than sintered carbide tools.

A great deal of research on this subject has already taken place—especially in the United States, Russia and Britain—and the results of some experiments have been published. For those who wish to study the literature and evaluate what may revolutionize machine shop operations, the Science and Commerce Department of the Sheffield City Libraries has produced a select bibliography on ceramic tools as No. 64 in the series of Research Bibliographies.

Copies of this bibliography, which contains 43 references, may be obtained free upon application to the City Librarian, Surrey Street, Sheffield 1.

THE telephone number of the Scottish Office of Wild-Barfield Electric Furnaces, Ltd., at 147 Bath Street, Glasgow, C.2, has been changed to City 4878.

Heat Treatment of Transmission Gears

David Brown's New Plant

A SPECIALLY designed heat treatment station, capable of processing 1,000 lb. of commercial vehicle transmission gears every 7 hours, has recently been installed by the Automobile Gearbox Division of David Brown Industries, Ltd., at Park Works, Huddersfield. The final design of the new station was evolved after a comprehensive investigation carried out by the David Brown Research Department, in the course of which hundreds of gears, made in different grades of steel, were tested in various states of heat treatment.

Before the new station was laid down, all production carburising was carried out by the pack method and the furnaces used for this operation were horizontal electrically heated batch type units, whose charge of 3,000 lb. of work was loaded by mechanical means. All re-heating was conducted in smaller type units, and most of the parts were free quenched in conventional tanks.

Factors Influencing Development

Because of the elaborate manufacturing procedure, no acute heat treatment problems were encountered, and all efforts could be concentrated on obtaining metallurgical excellence of the text book type. The replacement of profile ground teeth by shaved ones, and of straight sided splines by those of involute form, and the correspondingly increased demand for greatly reduced distortion, preservation of the surface finish, freedom from superficial damage and increased fatigue resistance, made it necessary to introduce new methods of heat treatment capable of meeting these more exacting requirements.

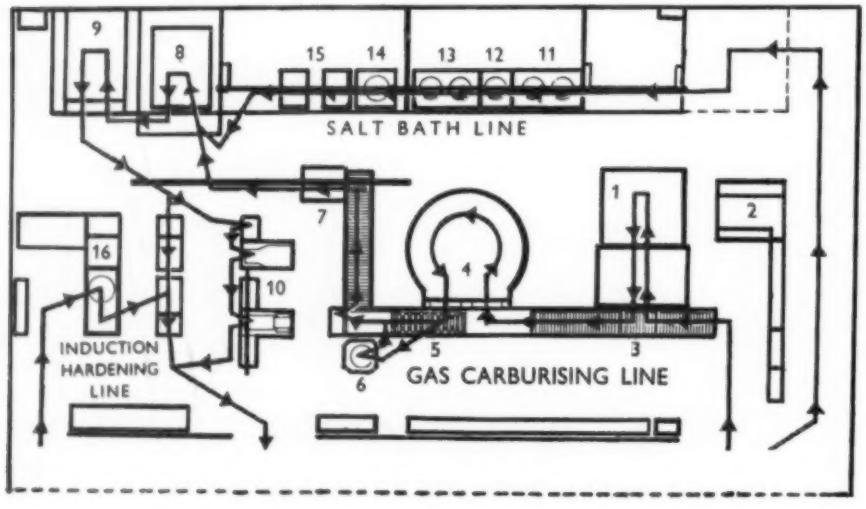
At this time there had been a rapid growth in gearbox output, and what had started as a jobbing line had developed into a specialised product with a large manufacturing section of its own, and it was natural, therefore, to think in terms of an in-line station where simplified heat treatment operations could be carried out. When it was found, however, that lack of space did not permit this, a compromise was made whereby all gearbox work was diverted to a gas carburising station recently installed for other types of gears.

This was not entirely the ideal solution, since none of the carriers or jigs had been designed for this class of work, but it did permit scale-free refining and exact control to be exercised over the quality of the carburised case. Heating for hardening was continued in the batch type normal atmosphere units, and increased use had to be made of quenching jigs and of the automatic Gleason press.

It has been known for some time, of course, that the rather elaborate heating cycles of the conventional case hardening schedule did much to increase the tendency of a gear to distort, and soon doubts began to arise as to whether in fact the text book type of quality always went hand in hand with maximum strength. To prove or disprove this, a major investigation was embarked upon, which involved the testing of hundreds of gears in different grades of steel, and in different states of heat treatment ; soon it became abundantly clear that many of the pre-conceived ideas would have to be discarded, and that factors in gear design previously neglected had considerable effect on a gear's resistance to fatigue.

As this knowledge grew, it became possible for the heat treatment schedule to be simplified, and for a picture to be formed as to the type of in-line plant that would be required and the equipment it would contain. The building of the new Automobile Gearbox Factory in 1955, made it possible to turn into reality all the concepts and ideas that had formed over the years.

Designing the station was not without its problems, however, and not least of these was how best to compress all the units into the available floor space, and how best to cater for the wide variety of parts that would flow through in small batch lots. This last factor largely



1 Gas carburiser
2 Control panels
3 Work Conveyor
4 Rotary hearth furnace
5 Quench tanks
6 Die quench tanks
7 Degreasing unit
8 Shot blast unit
9 Tempering furnace
10 Straightening process
11 Salt carburising unit
12 Cooling pot
13 Salt hardening unit
14 Quench tank
15 Wash tanks
16 Induction heating unit

Fig. 1.—Work flow diagram.

determined the choice of a three-line station with individual units of the compact batch handling type (see Fig. 1).

Gas Carburising Line

The first and main heat treatment line was planned to take the bulk of the transmission gears which flowed in regularly, and in suitable batch quantities and weights. For carburising these parts the choice was a horizontal gas carburising plant heated by means of gas-fired radiant tubes. The changeover from electric element to gas was not made without careful consideration, but the use of radiant tubes meant that not only could the nickel-chrome lining (always a potential source of maintenance worry) be dispensed with; but an external atmosphere generator was unnecessary, since the tubes themselves could be designed for this purpose. Furnaces of this type are generally constructed to allow for direct quenching of the work, but since most gearbox gears need individual attention during quenching, the construction was altered so that the work could be slow-cooled in a gas-tight pit.

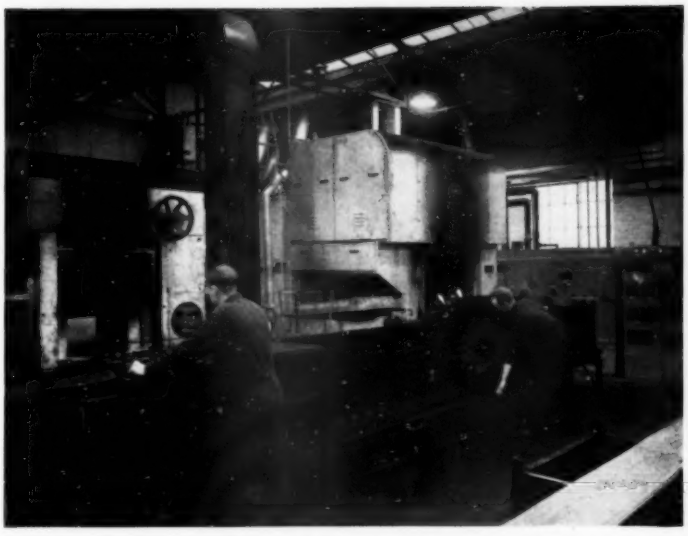


Fig. 2.—Rotary hearth furnace with built-on quenching tank. Work is discharged through the right-hand door and discharged through the door shown on the left.

The work is packed in rectangular containers standing on a roller conveyor of convenient height, and when packing is completed the charge is raised to the furnace sill on a hydraulic table, so that it can be pushed into the vestibule of the furnace. From this point onwards, the charging operation is automatic, since all furnace movements are push-button controlled; after closing the outer vestibule door and opening the inner door, two rotating screws draw the box to the rear of the furnace and the operation is repeated for the next box.

The heating rate of this furnace is greater than that of the conventional unit, since there is powerful forced circulation through the charge, while special refractory walls between the tubes and the boxes function as reservoirs of heat. Throughout the heating cycle a neutral carrier gas is generated in the inner tubes, and this prevents scaling or decarburisation of the work. During the active carburising stage the atmosphere is enriched with butane gas metered into the furnace.

In order to obtain the optimum quality with the simplified heat treatment, fine grained steels are used exclusively, and the processing temperature and the active-carburising-time : diffusing-time ratios are closely controlled to give the most suitable carbon gradient in the case and absence of grain coarsening of the core.

In spite of the fact that "normal" (i.e., not high) temperatures are used, the rapid heating ensures a short carburising cycle, and with this unit a charge of 1,000 lb. of work can be processed every 7 hours. There is no undue delay in emptying and re-charging the furnace, since the completed charge can be push-button transferred from the furnace and sealed in the cooling chamber without having to open the outer door. This is a considerable advantage when working in the line, since there can be no complaints of smoke or radiant heat from an exposed heavy charge of work.

When the charge has cooled to room temperature, it is brought up on the lift and transferred along the conveyor to the re-heating furnace, which is of the variable speed rotary hearth type (Fig. 2). This unit is electrically heated and is atmosphere sealed. Interesting features of this plant are the provision of a charging sill at charging level, and the fact that the quenching tanks are set immediately in front of and under the discharge door. This arrangement eliminates all need for lifting and carrying hot work. To avoid any possibility of the oil vapour igniting when the discharging door is opened, the tanks are made as small as possible and an extracting system is fitted just above oil level, so that the fumes never escape out of the top of the tanks; this system also serves to keep the line free from objectionable fumes or smoke. Since the doors are operated by foot pedals, the hands are free to work the valves controlling the hydraulic tables inside the tanks. No up and down movement of the work is required, since oil is pumped into the tanks at a rate of 300 gal./min., and this provides sufficient agitation with the table stationary in the tank. The exhaust system was later extended to take away all fumes from the draining boards and the Gleason press.

After hardening, the gears are taken along another horizontal conveyor where they are degreased and then cleaned by blasting with fine round shot. As with all other equipment in this line, considerable thought has been given to the question of ease of handling, and both the shot blasting cabinet and the tempering unit have been set in pits so that there will be as little lifting as possible.

In fact, the H.F.C. tempering unit has been set so low that the hearth is level with the floor; containers with as much as half a ton of work can easily be charged into the furnace with a small lift truck. Considerable importance is attached to the tempering of transmission gears, and a very rigid time-temperature cycle is set from which no departure is permitted.

Salt Bath Installation

The second heat treatment line, which is intended to cater for all the small quantity parts and those which cannot be accommodated economically in the gas carburising unit, consists of salt bath furnaces, cooling

pits, quench and washing tanks, all built into a rectangular unit and enclosed by a hood with its own fume extraction system. Since the work has to be lifted and lowered vertically in each operation, a monorail hoist with a station index serves the whole unit.

The work is first loaded into basket-type carriers and is not disturbed until the final washing operation is completed. The sequence of operations along the line is: preheat, carburise, cool in sealed tank, preheat, heat for hardening, quench, wash and unload; whilst this would appear to be complicated, the whole sequence is carried out quite easily, thanks to the efficiency of the overhead hoist. Considerable ingenuity had to be exercised when designing the carriers, since they had to provide support during heat treatment and yet be free in the cooling pits and quench tanks. The solution was found when three-pronged spiders were built into the top of the carriers. Both salt baths are automatically temperature controlled and have proved to be extremely efficient in use, a case depth of 0·040 in. being obtainable with a work charge of 250 lb. in a total cycle of 4½ hours.

The oil system for the quench tanks presented its own difficulties, since it was considered desirable not to incorporate heat exchangers of conventional form; the ultimate solution involved provision in the basement of two oil storage tanks of larger capacity than normal, oil being pumped up into the quench tanks and then returning over the weirs and down special ducts where it is cooled by natural air convection. In practice this has worked very well, and even at the end of the working week the temperature does not reach the accepted "danger" limit.

Induction Hardening Plant

The third heat treatment line was made necessary by the large amount of non-gear parts in the modern gearbox which require some form of local hardening. Whilst in the past it has been customary to treat them by cyaniding or local case hardening, the induction hardening process appeared to be very attractive for this type of work. The conventional design of work head, however, would not be capable of processing the wide variety of parts concerned, and after consultation with the makers it was decided to instal a 25 kW. valve oscillator set with the energy output leads coupled to a capstan type workhead, an arrangement which allows four permanent hardening fixtures to be used. Since the main application is the surface hardening of selector rods, a vertical traverse is incorporated in the head, and all switching of the high frequency power is controlled by switch contact templates made to suit each design of rod. Like most plants of this kind, the processing proceeds automatically once the controls are set and the start button is pressed.

Plant of this type finds many uses in the modern factory, and its ability to soften as well as harden is exploited to anneal the hardened keyways and screwed portions of shafted gears; consequently it is found possible to eliminate all need for copper plating in the gas carburising line.

The changeover from case hardening to induction hardening for most of the non-gear parts meant that the alloy steels could be replaced by the more readily available and less expensive carbon steels without loss of performance in service.

Summarising, it is considered that with the three heat treatment lines and the equipment they contain, an ideal compromise has been made between jobbing and repetition mass production hardening, so that on a relatively confined floor space there is a compact plant capable of satisfying all demands placed upon it.

Considerable thought has gone into the design of the ancillary plant so that the operators can be relieved of the manual effort usually necessary in hardening operations of this kind. By building most of the plant to the company's own design, it has been possible to incorporate special handling equipment at relatively low expense.

With plants of this type, development work is continuous, and at the present time work is going ahead on the design of an automatic programme controller for the gas carburising unit, which, when installed, will control the furnace atmosphere and the carburising cycles, thus making the carburising operation fully automatic.

Industrial Setting for Student Conference

DURING his first year as head of the Department of Industrial Metallurgy, University of Birmingham, PROFESSOR E. C. ROLLASON has introduced an interesting innovation into the curriculum of his students. Traditionally, undergraduates and graduates of the Department are invited towards the end of each Easter term to take part in a conference featuring some aspect of their work. This year, the subject chosen was "Industrial Organisation and Administration." At Professor Rollason's suggestion, this took place not at the University, but on the premises of a large industrial concern—the headquarters of the Metals Division of Imperial Chemical Industries, Ltd.

The conference was attended by some sixty members of the Department—honours degree students and graduates—who heard papers given by senior officials of the Company on the following subjects: "Organisation and Application of Scientific Research in I.C.I.," by DR. N. P. INGLIS (Research Director); "Design and Layout of Non-Ferrous Factories," by MR. W. N. ISMAY (Technical Director); "Works Administration and Production Control." by MR. C. L. M. COWLEY (Production Manager for Light Alloys); and "Company Structure and its Effect on Staffing and Training," by DR. G. A. W. PIKE (Staff Manager). As a practical example of the progress of a "new" metal from laboratory to large-scale commercial production, students were told the story of titanium and toured research and production units devoted to this metal.

Pipework Contract at Atomic Plant

A CONTRACT for the installation of pipework at the atomic plant at Springfields, near Preston, has been awarded to Mitchell Engineering, Ltd., by the Atomic Energy Authority. Work in this contract falls into several stages and the value of the first stage is estimated at several thousand pounds. This contract is the fifth to be awarded to Mitchell companies by the A.E.A. for civil engineering and pipework on atomic projects.

Cor-ten Licensees

THE United States Steel Corporation announces that it has enlarged the group of steel producers licensed to manufacture and sell Cor-ten—its corrosion-resistant, high-strength, low-alloy steel—by licensing the South African Iron and Steel Corporation (ISCOR) of Pretoria, and de Wendel & Cie., S.A. of Paris.

Autosonics

Automatic Ultrasonic Inspection

AS long ago as 1924, Kelvin & Hughes, Ltd., (then Henry Hughes & Son, Ltd.), began experiments with sound waves, using the echo principle, for indicating the depth of the sea. This system used sonic frequencies, and was soon superseded by a supersonic system using magnetostriction transducers and electrolytic recording. These techniques resulted in the now famous Kelvin Hughes range of echo sounders.

Development of Ultrasonic Inspection

In 1943, Kelvin Hughes extended the echo technique to the ultrasonic inspection of solids, and the system developed was successfully used in the examination of armour plate and aircraft main spars. These early instruments were further developed, and today the ultrasonic technique of non-destructive testing finds widespread application for the inspection of finished and fabricated products under all possible conditions. In the course of these developments, the knowledge and experience gained in one application has contributed to further progress in another, and so a considerable amount of "know how" has been acquired by the company's technologists. The most recent development, and a logical outcome of what has gone before, is "Autosonics"—a fully automatic system of ultrasonic flaw detection. Before describing the new technique, the principles of ultrasonic flaw detection and the manual operation of the equipment may usefully be discussed briefly. Ultrasonic inspection uses a beam of high frequency sound to detect the presence of discontinuities in the material under test. An acoustic transducer is coupled to the surface of the material by liquid, and transmits sound into the material as a sequence of energy pulses. These pulses are reflected from the opposite surface of the material and returned to the probe. The time taken is dependent upon the velocity of sound in the material and its thickness. This sequence of events is displayed as a trace on a cathode ray tube (Fig. 1). Vertical deflection of the trace indicates amplitude of ultrasonic sound, and horizontal deflection of the trace is proportional to elapsed time. The presence of any discontinuity in the material returns a part of the transmitted sound before that from the boundary, creating a vertical deflection of the trace on the cathode ray tube (Figs. 1*b*, and 1*c*) enabling the operator to establish the presence and position of the defect from the relative position of the probes, and the trace on the cathode ray tube.

Although manual ultrasonic inspection has served a useful purpose—and still does—it has a number of limitations. It is, for instance, dependent on the operator being able to maintain constant vigilance of the cathode ray tube, while, at the same time, manipulating the inspection probes: this gives rise to operator fatigue and inefficient inspection over long periods. Manual inspection is a slow process, unsuited to handling large volumes of material, and as it cannot easily be applied at every stage of manufacture, it is generally used for sampling rather than for continuous control of quality.

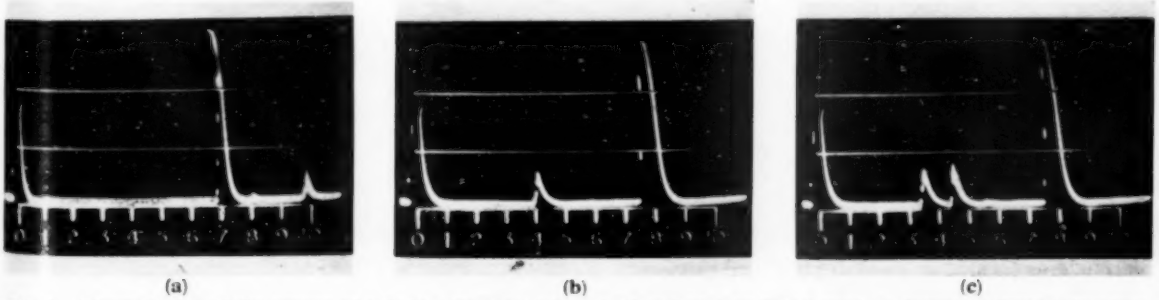
Advantages of Autosonics

Besides overcoming the limitations of manual inspection—for which its development was initiated—Autosonics offers a number of additional advantages. Quite apart from the speeding up of the inspection procedures and the elimination of operator fatigue, the new technique ensures reliable maintenance of predetermined inspection standards, and the equipment may now be integrated as a part of a production line. In such cases, because of the ease with which the results of inspection may be automatically plotted, it would be possible to provide a continuous record of production quality.

The most obvious differences between Autosonics and manual inspection are the automatic traversing of the probes and the audible or visible warning of defects which are features of the new technique. There are, however, other less obvious but equally important features, as will be seen from the following description of the new equipment.

Electronic Circuits

Autosonics is based on a combination of electronic circuits and mechanised manipulation. The former comprise the following sections: the flaw detector section; the automatic gain control section; the automatic flaw alarm and recorder section; and the system fault alarm section. After a simple intial setting-up procedure, these sections replace the operator, performing his functions with rapidity, certainty and accuracy.



(a) (b) (c)

Fig. 1.—Photographs of the screen of a Kelvin Hughes' Mark 5 Flaw Detector being used to inspect a forged titanium billet. (a) indicates sound material; (b) indicates one defect; and (c) indicates two defects.

Fig. 2.—The demonstration equipment installed in the Kelvin Hughes Research Laboratory at Barkingside. The probe is being set for immersion testing of a billet.

Initial adjustments are made particularly easy by the novel method of display on the cathode ray tube screen, e.g., in a single channel equipment there are two sections of the traces which are brighter than the rest. These bright portions define the position of the electronic "gates" essential to the operation of the succeeding automatic circuits. The purpose of these "gates" is twofold. Firstly, they select defect indications from all or only selected strata in the cross section of the material. Secondly, they select only those defect indications which are greater than a preset amplitude.

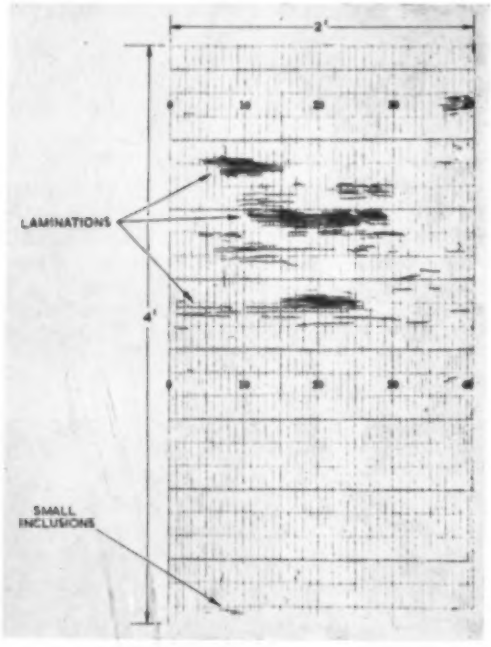


Fig. 4.—A reproduction of a P.P.I. (plan position indication) recording taken from a steel plate 4 ft. × 2 ft. × 1 in., showing the plan position of areas of laminations and small inclusions.

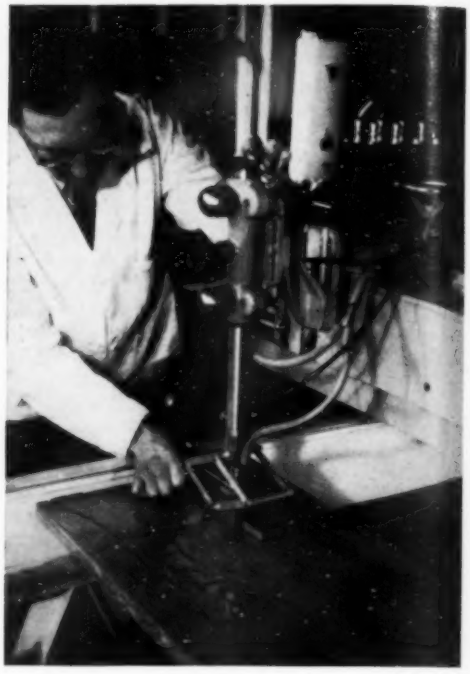


Fig. 3.—Setting up the probe for gap testing of steel plate on the demonstration equipment.

The flaw detection section generates ultrasonic sound which is transmitted into the material, as a sequence of energy pulses, by an inspection probe, coupled to the surface of the material by a liquid. It also amplifies the reflected pulse, and presents the complete sequence of events as a trace on a cathode ray tube screen.

One of the most important of the electronic circuits is the automatic gain control section, which maintains the sensitivity of inspection constant by monitoring the amplitude of a selected echo pulse and, whenever necessary, altering the gain of the amplifier to compensate for any change in it. In this way, any particular defect will give a reproducible indication.

The automatic flaw alarm and recorder section operates warning lights, bells or klaxons when a flaw indication is obtained on the cathode ray tube screen. It can be adjusted to respond to indications from defect signals in any section, or only to signals from separate narrow strata which can be set anywhere in the cross-section. Sensitivity can be adjusted so that it will respond to small or large indications, ignoring those which are less than the preset level. Finally, the output from this section can be used to operate various recording systems, e.g., to provide a plan position indication of any defect present in a plate.

In the event of the selected monitor signal falling below its control level for any reason, an alarm will operate which will stop the scanning machinery. This alarm will operate until the fault is corrected, and only then can it be reset.

An important feature of Autosonics is that a predetermined scan or search plan is accurately followed by the probe system, thus ensuring that all information relevant to the size of the defect and its position in the specimen is indicated and recorded. Selection of the

Fig. 5.—Equipment used for the semi-automatic detection of lamination in steel plate.

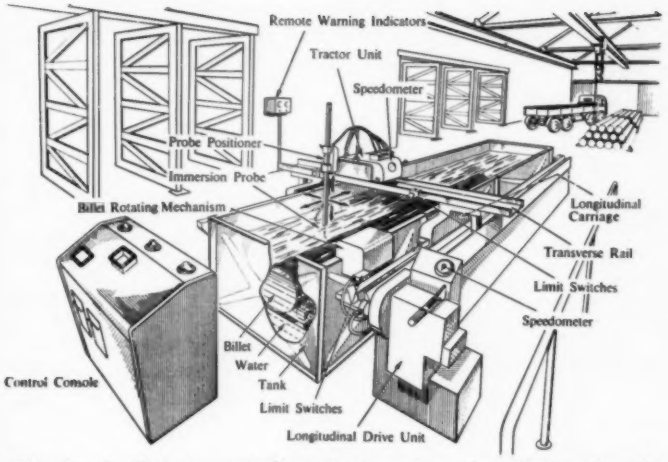


Fig. 6.—A diagrammatic impression of an installation for the automatic inspection of light alloy billets by a total immersion technique.

type of scan and recorder is governed by the nature and position of the probable defects, the dimensions and shape of the specimen and production conditions.

There are three techniques of ultrasonic inspection, namely, contact testing, gap testing and immersion testing. In the first of these, the probe is coupled to the surface of the material by means of a thin film of liquid between the two, whereas in gap testing there is between the probe and the material surface a small but definite gap, which is filled by a constant flow of liquid. In immersion testing both sample and probe are immersed in the liquid, and the distance between the two is much greater.

Mechanised Testing

A range of mechanised testing equipment has been developed for the application of Autosonics, and a typical demonstration installation is shown in the accompanying illustrations. It consists essentially of a large tank straddled by a bridge structure which can be moved longitudinally. On this bridge structure there is a carriage which can be traversed across the width of the tank, and on one side of which is mounted a probe support column which is adjustable for height. This probe is used for demonstrating the immersion testing of an aluminium billet, the billet being rotated as the bridge moves up and down the tank.

On the other side of the carriage is mounted a gap testing probe used for the inspection of steel plates liable to contain laminations. The plate remains stationary, while the combined longitudinal movement of the bridge and reciprocating transverse movement of the carriage serve to traverse the probe over the whole area of the plate. Liquid pumped from the tank serves to couple the probe and workpiece. The equipment is coupled to a chart recorder in which the speed of movement of the chart is related to the longitudinal speed of the bridge, and the movement of the pen is related to the transverse movement of the carriage. The position of defects is indicated on the Teledeltos paper of the chart. The introduction of such an installation as part of a production line at the plate mill would make possible the provision of a continuous record of production quality besides facilitating the selection of sound portions of partially defective plate. The equipment can also be modified so that the defective areas are marked on the plate itself.

In what is described as semi-manual testing of plate, the probe is mounted on a hand propelled carriage—somewhat reminiscent of a carpet sweeper—which incorporates a tank and provision for maintaining a supply of liquid in front of the probe as it traverses the plate.

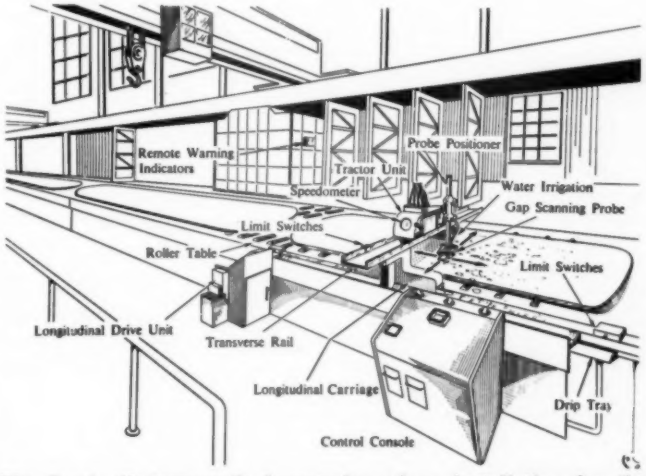


Fig. 7.—A diagrammatic impression of an installation for the automatic detection of lamination in steel plate by a gap testing technique.

The fully automatic technique can be applied to long seam welds, indicating lack of penetration, porosity, cracking, etc., and this may prove an important field for Autosonics, whether for final inspection or preliminary assessment of quality.

For inspecting small production parts, such as billets for drop forging purposes, a sequence testing unit can be arranged in which the parts are mechanically applied in quick succession to a head incorporating a static probe.

Specification

Frequency Range : 0·5–10 Mc./s. Frequencies up to 25 Mc./s. available to special order.

Inspection Range : Up to 25 ft. (8 m.).

Probes : Common, combined or separate transmitter and receiver systems.

Widths : ¼–6 in. (5 to 150 mms.).

Pulse Lengths : Down to 3 cycles at half power level.

Dead Zones : 0·1 in. (2·5 mm.) at 2·5 Mc./s. test frequency for targets equivalent to a $\frac{3}{64}$ in. diameter (1·25 mm.) flat bottom hole in aircraft type materials; 0·01 in. (25 mm.) at 2·5 Mc./s. for gross laminar type defects.

Automatic Monitoring and Flaw Alarms : Adjustable from 0·1 in. (2·5 mm.) below top surface to 25 ft. (8 m.) both in location and width.

Inspection Speeds : For targets equivalent to $\frac{3}{64}$ in. (1·25 mm.) flat bottom hole up to 100 ft./min. (30 m./min.). For gross defects up to 400 ft./min. (120 m./min.).

Personal News

Mr. F. H. Roberts has been appointed a Director and Chief Engineer of John Thompson (Australia) Pty, Ltd., a member company of the John Thompson Group. He has played an important part in the development of power station plant using Victorian brown coal and New South Wales black coal and briquettes.

Mr. E. O. Faulkner, M.B.E., a Managing Director of Glyn, Mills & Co., Deputy Chairman of Union Discount Co. of London, Ltd., and a Director of Hudson's Bay Co. and Richard Thomas and Baldwins, Ltd., and Mr. G. H. Houlden, C.B.E., a Director of Vickers-Armstrongs, Ltd., and Managing Director of Vickers-Armstrongs (Shipbuilders), Ltd., have been appointed to the Board of Vickers, Ltd.

The appointment is announced of Mr. J. I. Bernard, as the new Director and Secretary of the British Electrical Development Association in succession to Mr. V. W. Dale. Mr. Bernard joined the staff of E.D.A. in 1928 and has been its Chief Technical Officer since 1936.

Mr. C. J. Williams has relinquished his position as Manager of the Casting Division of High Duty Alloys, Ltd., and has taken up an appointment with A. Wigley (Belper), Ltd., of Horsley Woodhouse, Derbyshire, as their Sales and Technical Director.

Mr. K. C. Lodge, Commercial Manager and Secretary of Owen and Dyson, Ltd., Rotherham, retired on March 31st after 46 years' service. The responsibility for his duties now devolve upon Mr. W. T. Vizer-Harmer, Commercial Manager of Steel, Peech and Tozer, on the one hand, and Mr. R. Spencer, Secretary of Steel, Peech and Tozer, on the other hand. In commercial matters, Mr. F. E. Jobson, Sales Manager (Railway Materials) of Steel, Peech and Tozer, will act for Mr. Vizer-Harmer, and in secretarial and office matters, Mr. H. H. Hawkins of Owen and Dyson, will act for Mr. Spencer.

Professor H. S. Lipson, Director of the Applied Physics Laboratories in the Faculty of Technology, University of Manchester, has been elected to a Fellowship of the Royal Society.

Mr. A. P. Wickens has been appointed Managing Director of Vickers-Armstrongs (Tractors), Ltd., and ceases to be a Director of Vickers-Armstrongs (Engineers), Ltd., and General Manager of the Elswick, Scotswood and Wakefield Works of that Company. He is succeeded as General Manager by Mr. J. R. Kelly. Mr. J. G. Lloyd has been appointed a Director of Vickers-Armstrongs (Engineers), Ltd., and General Manager of the Crayford, Dartford and Thames Ammunition Works of that Company. Lt.-Comdr. R. B. Lakin, D.S.O., D.S.C., has been appointed Managing Director of George Mann & Co., Ltd.

Mr. B. Trehearne, formerly Development Officer at the British Welding Research Association has been appointed by Langley Alloys, Ltd., to develop a welding section for corrosion resistant copper- and nickel-base alloys. The development work will embrace the welding of aluminium bronzes, Hastelloys, Monel, etc.

Mr. E. N. Horley, who rejoined Foundry Services, Ltd., after completing his National Service, to train as an overseas technical representative, left this country on April 7th charged with the interesting mission of looking into conditions and opportunities for expansion in Mexico, Peru, Venezuela, Colombia, Cuba, Panama, and the West Indies.

The Coil Spring Federation Research Organisation have appointed Mr. R. Haynes to be Director of Research at their new laboratories at Hoyle Street, Sheffield. Dr. R. Genders, M.B.E., is relinquishing his position in this connection, and will maintain his association with the Organisation in a consultative capacity.

Councillor W. G. Pallett, J.P., has accepted an appointment as Managing Director of Brayshaw Furnaces & Tools, Ltd. Mr. Pallett is a member of the Sheffield City Council and was until recently Managing Director of the Laycock Engineering Co., Ltd., Sheffield. Mr. W. T. C. Roden has taken up the position of Technical General Manager of Brayshaw Furnaces & Tools, Ltd.

Johnson, Matthey & Co., Ltd., announce the election of Mr. G. C. H. Matthey as Chairman, following the recent death of Mr. H. W. P. Matthey. Mr. G. C. H. Matthey was appointed a Joint Managing Director of the Company in 1913, and served in this capacity for 35 years.

Mr. J. O. Hitchcock, a Director of The Mond Nickel Co., Ltd., has been elected a Director of Henry Wiggin & Co., Ltd.

Mr. E. J. Catchpole has been appointed Manager of the Bonded Structures Division of Aero Research, Ltd., Duxford, Cambridge.

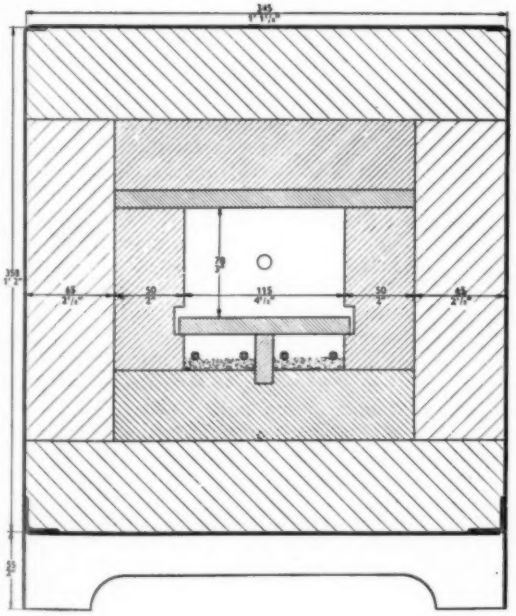
New Heating Element Material

Suitable for Temperatures up to 1,600° C.

A NEW electrical heating and resistance material which is claimed to surpass all the known heater materials based on non-precious metals and silicon carbides, due to its refractory properties, and which furthermore can be formed into the shapes which are most suited to the particular heating requirements, has been developed by Aktiebolaget Kanthal, Hallstahammar, Sweden*. Known as Kanthal-Super, the new material has the structure of a cermet—i.e. it is a powder metallurgical product consisting partly of a metal or metalloid material, and partly of a ceramic material. The chief components are $MoSi_2$ and SiO_2, together with other metallic and ceramic materials which are added to modify the mechanical and thermal properties.

Kanthal-Super is intended for use at element temperatures as high as 1,600° C., since it will tolerate as heavy surface loads as 64–128 watts/sq. in. Elements are of the hairpin type with heating zones 6 mm. (0·236 in.) in diameter and terminals 12 mm. in diameter. Material having smaller diameters can be made for special purposes.

* Sole Agents for United Kingdom: Hall & Pickles, Ltd., Manchester and Sheffield.



Number of elements 1
Resistance of element when hot 0·106 ohm.
For maximum furnace temperature of 1,450° C. the following rates apply :
Power ... ... 1,800 watts
Starting voltage ... ... 5 volts.
Operating voltage ... ... 14 volts.
Current ... ... 130 amps.
Heating time (approx.) ... ... 4 hours
Desirable operating voltages ... ... 12·5, 14, 15·5 volts

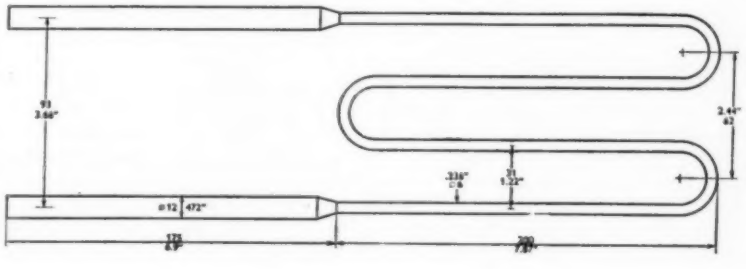


Fig. 1.—Single element box furnace. Dimensions of furnace and element in millimetres and inches.

Properties

Kanthal-Super is brittle and very hard : it has relatively high bending and tensile strength, but low impact strength. Below 1,100° C. it should not be submitted to any considerable breaking or impact stress, but above that temperature new material is quite ductile, and at higher temperatures can be bent or wound to elements of desired shape. Elements used previously cannot, however, be subjected to such treatment. At 20° C. Kanthal-Super has a hardness of 70 Rc and a bending strength of 35,800–66, 600lb./sq. in. The tensile strength at 1,550° C. is 107–177 lb./sq.in., and the elongation 4–5%.

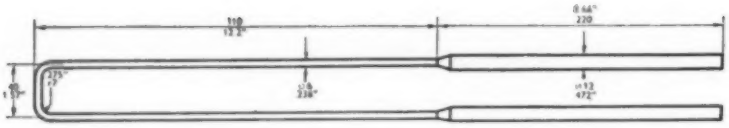
The specific electrical resistance of Kanthal-Super rises rapidly with temperature, values for 20° C. and 1,600° C. being $0{\cdot}4 \times 10^{-4}$ ohm. cm., and $3{\cdot}5 \times 10^{-4}$ ohm. cm., respectively. As a result, for a constant voltage the power consumption falls as the temperature rises. This fact helps the rapid attainment of the desired furnace temperature, and prevents the elements being overloaded.

Since the sintering process continues during the first few hours of operation, the density of new Kanthal-Super elements increases, so that the resistance falls slightly. This change in resistance ceases after 2–10 hours, depending on the temperature at which the element is run. No further change takes place in the specific resistance, so that new and old elements can be connected together without difficulty.

Electrical Supply Requirements

Since no ageing occurs with the new material, furnaces with a large number of heating elements may be connected directly to the mains. The elements have a low resistance at low temperatures, however, so that heavy current surges occur when they are first switched on. For this reason, a starting voltage about one third of the operating voltage is required, and it has been found advisable to keep the low starting voltage on for 10–15 minutes before applying the full working voltage.

Any transformers which may be used should have provision for regulating the voltage over a range of ± 10% of the calculated working voltage. In cases where the elements are used for widely differing furnace temperatures, or the furnace charge requires a long



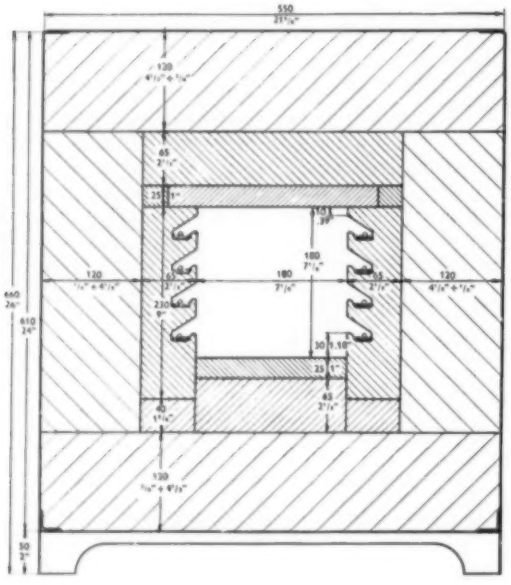


Fig. 2.—Multi element box furnace. Dimensions of furnace and element in millimetres and inches.

Number of elements	4
Resistance of element when hot	0·082 ohm.
For maximum furnace temperature of 1,450° C. the following rates apply :	
Power	5,000 watts
Starting voltage...	12 volts
Operating voltage	40 volts
Current	124 amps.
Heating time (approx)	5 hours
Desirable operating voltages	36, 40, 44 volts

heating-up process, continuously variable transformers or transformers with a large number of taps are recommended. Chopper bar instruments and platinum/platinum-rhodium thermocouples are most suitable for temperature control purposes. In order to prevent the elements and the furnace being overheated should the thermocouple fail, it is desirable to provide a chopper bar regulator with a contact protection system for, say, 400° C.

Element Life

The life of the elements depends primarily on the conditions in the furnace, such as frequency of heating and cooling, element temperature, surface loading, furnace atmosphere, material used for the ceramic supports, and cooling conditions. With a new material, of course, industrial experience on this matter cannot be quoted, nor is there yet a direct answer to the question of how long these elements will withstand various temperatures. On the other hand, elements which have been tested in experimental furnaces are still running after a year's continuous operation at an element temperature of 1,500° C., and show no alteration. Excellent results have been obtained with intermittent operation, but the longest life is to be expected where the furnace is used continuously, particularly at the highest furnace temperatures, where the danger is greatest that the elements will not be able to move freely on cooling. Where it is tolerable on practical and economic grounds, it is recommended that the furnaces should be run at 600–1,000° C. during their idle periods. Since the risk of the element fracturing, due, for example, to sticking to the furnace lining, overheated connections or thermal stress, increases with rising temperature, it is probable that a longer life will be obtained at element temperatures lower than the maximum permissible.

The shape of the furnace and the elements, the continuity of operation, the material used for bricks, the furnace atmosphere, and the nature of the charge, are all factors which affect the flow of heat from the elements, and this makes it impossible to quote values of general validity for the optimum surface loading. Nevertheless, as a rough guide, the following figures are given by the makers : 1,200° C.—129–193 watts/sq. in. ; 1,550° C.—19·5–32 watts/sq. in. The best life is obtained in oxidising atmospheres such as air, oxygen, steam and carbon dioxide, although good results can be obtained in reducing gases such as carbon monoxide, cracked ammonia and hydrocarbons, if the elements are first oxidised for a few hours in a current of air. Pure dry hydrogen forms a silicon-hydrogen compound with the surface layer of the element, with the result that the latter is gradually consumed. The elements will tolerate hydrogen, however, provided that it is mixed with small quantities of a gas containing oxygen—e.g. steam. Sulphur and sulphur compounds, and metals and enamels which form easily fusible compounds with silicon, silicic acid or silicates, should not be allowed to come into contact with Kanthal-Super.

In order to prevent breakage, the heating element must be able to move freely both on heating and cooling. With element temperatures up to 1,450° C., the heating conductors can be laid directly on the furnace supporting brick without trouble. At higher temperatures, however, the silica layer which protects the elements against premature oxidation becomes soft, and has a tendency to cause the elements to stick to the furnace lining. It is advisable at temperatures from 1,450–1,530° C., to lay them on a bed of coarsely powdered sillimanite tiles. For the highest element temperature—i.e. 1,600° C.—it is desirable to suspend the heaters without supporting bricks.

In order to prevent any reaction with the furnace lining, with consequent damage to the element, it is important that the most suitable brick material should be used. Sillimanite bricks containing 60–70% Al_2O_3, 30–40% SiO_2, and a maximum of 1% Fe_2O_3 have proved satisfactory. Bricks with a higher SiO_2 content and bricks containing silicon carbide can also be used.

Strength of Single Metal Crystals

RESEARCH Bibliography No. 63 compiled by the staff of the Science and Commerce Department of the Sheffield City Libraries is a select bibliography on the strength of single metal crystals. This bibliography contains 52 references which are briefly annotated wherever necessary. Copies may be had free upon application to the City Librarian, Central Library, Surrey Street, Sheffield 1.

Measuring Hot Steel Strip Thickness

Gamma Ray Gauge Installation

General view of hot strip mill showing strip passing the measuring point.

CLOSE control of thickness or weight per unit area during the manufacture of steel strip is important for several reasons. Strip is sold at a given price per ton, and as the number of parts which can be made out of a ton is inversely proportional to the mean strip thickness, weight per unit area is an important economic factor. On the technical side, the quality of the product is likely to be better if the tools are used on strip of the thickness for which they were designed.

Mechanical contact gauges cannot be used to check the thickness of material at red heat, and for this purpose non-contact gauges are required. Among gauges of this type developed in recent years, those depending on radiation figure prominently. A radiation gauge consists of a source of ionising radiation—radioactive isotope or X-ray tube—and a detector responsive to ionising radiation, with associated amplifier and indicator, recorder or controller.

The strip to be gauged passes between source and detector, and the ratio of transmitted to incident radiation is a measure of the weight per unit area of the interposed absorber. The relationship between this measured ratio and the weight per unit area of the absorber depends on the nature and penetrating power (energy spectrum) of the radiation; the geometrical relationship of source, absorber and detector; the composition (mean atomic number) of the absorber; and the characteristics of the detector. If these are constant, or accurately predictable and controlled, then the incident/transmitted radiation ratio is only a function of absorber weight per unit area.

Radiation gauges using the beta rays of radioactive elements are now well established and widely used in industry on both sides of the Atlantic. X-ray gauges are also in fairly general use, mainly on some types of steel rolling mills in the U.S.A.; and installations now exist in this country. The gamma ray transmission gauge is the youngest member of the family of radiation thickness gauges, but there is sufficient evidence to show that on hot steel mills the gamma gauge offers definite advantages.

A thickness gauge of this type has been developed by Baldwin Instrument Co., Ltd. It consists of five main units: the source unit and detector unit; the electronic cabinet; the display board; and the operator's control desk. The variations in radiation falling on the detector as a result of strip thickness variations are, after passing through the electronic equipment, displayed in two ways, namely on a lamp display board and on a teleprinter.

Rotherham Installation

The Baldwin installation at Steel, Peech and Tozer, Rotherham, a branch of The United Steel Cos., Ltd., is the first example of this instrument in continuous use on hot steel strip rolling, and a second one is to be installed in their Brinsworth mill in the near future.

The working example is on a Morgan strip mill rolling up to 9 in. wide strip, and is arranged to measure thickness between the limits of 0·03 in. and 0·250 in., the total span being divided into six ranges. Its regular use on such a mill enables manual gauging to be reduced to an absolute minimum, and is of considerable assistance in the setting up of the mill after a change in thickness. It also enables actual thickness to be known at all points along the strip, instead of, as in manual gauging, at one point near the end of a particular coil.

At the passing of the trailing edge of the strip through the measuring gap, the sudden increase in radiation falling on the detector is arranged to change the instrument from the "measuring" to the "standardising" condition, and a standard piece of material is interposed between the source and detector. Whilst the instrument is awaiting the arrival of the following strip, a servomechanism is correcting any drifts in the installation. Upon arrival of the next strip there will be a sudden decrease in radiation falling on the detector and this will cause the instrument to be restored to the measuring condition.

This installation, apart from the usual test meters and switches, has been provided with means to test various portions of the equipment without the use of other main units. For example, if a fault is suspected in the control

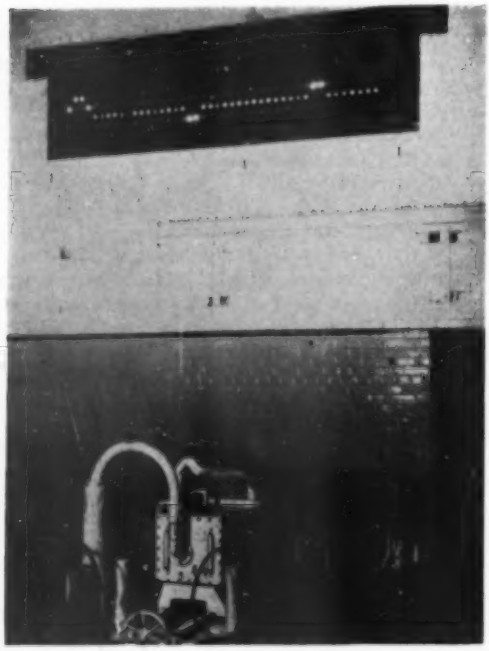
desk, a simple adjustment at the rear of the instrument enables the control desk to be disconnected entirely and replaced by a built-in test facility. As a further aid to simple maintenance, certain components, such as uniselectors and relays, are plug-in replaceable units.

Measuring Head

The measuring head consists of two units, the source unit and the detector. These two units are mounted one either side of the steel strip, so that the radiation from the source is directed at the detector. In passing through the strip, a certain amount of the radiation is absorbed, depending on the thickness of the metal, and thus the intensity of radiation reaching the detector is reduced. It will be appreciated that any variation in thickness will cause a corresponding variation in the radiation being measured by the detector and associated electronics. It is therefore a simple matter to calibrate the instrument directly in units of thickness.

The source unit houses the radioactive source, and is also fitted with special equipment which is brought into operation only when the instrument switches itself to "standardise." In this condition, a signal from the electronic unit causes a pneumatic cylinder to place a circular disc of metal of standard thickness over the radioactive source. The instrument then measures this standard and, if necessary, adjusts itself to give correct reading. There are, in fact, six standard metal discs in the source unit, and the appropriate one is preselected by means of a control on the operator's control desk. The complete unit is housed in a rugged water-cooled jacket.

The radiation sensitive element in the detector unit is a thallium-activated sodium iodide crystal which scintillates when radiation falls upon it. The visible light from the crystal is picked up by two photomultipliers, one of which acts as the measuring device for the instrument, the other as a relay which causes the changeover from the measuring to the standardising condition, and vice versa. The output from the measuring photomultiplier feeds into an integrating circuit which averages the current over the time cycle of one second. The output from the integrator is then fed to the amplifier in the electronic unit.



The display board with its fifty vertical rows of five lamps each. The board is mounted directly above the source and detector units and is clearly visible to the mill personnel.

When the trailing edge of the strip passes through the measuring head, there is a considerable increase in radiation reaching the crystal and a corresponding increase in visible light. The second photomultiplier measures this change and causes the instrument to switch to the standardising condition, whereupon one of the six standard discs in the source unit is moved into position, thus reducing the radiation reaching the crystal. When the leading edge of the next strip arrives in the measuring head, there is a sudden drop in radiation at the detector, the relay photomultiplier reacts to this and causes the instrument to be restored to the measuring condition.

The source and detector units are mounted on either side of the strip, which passes between them in the vertical plane through a water-cooled slotted guide. The units are easily separated for maintenance and removal of the guide by turning a handwheel, and may be moved in a vertical direction by adjustment of a control wheel on the operator's console. This allows the radioactive beam to pass through various points across the width of the strip and also accommodates the variation of strip width. This movement is carried out by a specially designed machine actuated by a power cylinder with accurate position control.

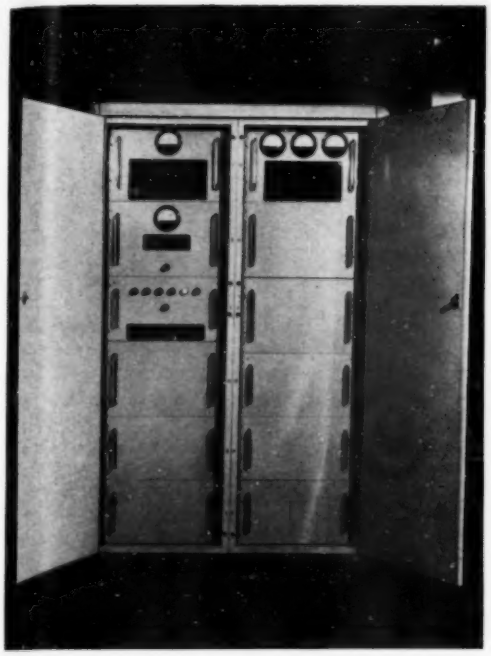
Electronic Cabinet

This cabinet contains the electronics which amplify the signals from the detector. The output from the amplifier is fed to a discriminator, which classifies each signal into one of five levels, depending upon the magnitude of the signal, which in turn depends upon the average thickness of strip passing through the measuring head during the appropriate second. The five levels are arranged to represent: out-of-tolerance positive, intermediate positive, nominal thickness, intermediate negative, out-of-tolerance negative. The five levels are represented by five banks of a uniselector which is stepping round at one second intervals over 50 contacts each.

Once every second an impulse is applied to one of the five uniselector banks, depending on the voltage of the signal entering the discriminator. The impulse will be fed to one of the uniselector contacts and the appropriate relay will be operated. It will be realised that each uniselector bank will represent one of the five conditions of thickness.

Display Board

This consists of five horizontal rows of lamps, each containing 50 lamps. In the horizontal plane, the centre row of green lamps represents nominal thickness, the two rows of yellow lamps either side of the centre representing the positive and negative intermediate tolerances, while the two outer rows of red lamps indicate the out-of-tolerance conditions. In the vertical



Electronic cabinet showing built-in test and simulator facilities.

Part of the operator's control desk showing alloy selector, set thickness control and tolerance control.

plane, each of the 50 banks of five lamps represents one measuring cycle of one second.

The lamps are operated by the relays which are connected to the contacts of the uniselector. Thus, for each second during which strip is passing through the measuring head, an impulse from the detector causes one of five lamps to light, depending on the deviation of the average thickness of the strip from the preset thickness. As the strip moves past the gauge, the lamps trace out the thickness profile. The display board is so sited that everyone concerned can see it and take whatever remedial action is necessary. In general the operator does not act on the results of an individual strip, but observes a trend before taking action.

As the display is cancelled the moment the leading edge of the next strip arrives, it is necessary to arrange for a more permanent record. This is done by using a Creed teleprinter. One of five keys is used to represent each of the five rows of lamps. In this way, the teleprinter shows symbolically whatever is shown graphically on the display board.

Control Desk

This unit contains all the controls which are necessary for the day-to-day operation of the equipment. These include a set thickness control, the required nominal thickness being set on this dial and the display board then shows deviations from this setting ; range selector, which preselects the standard metal disc for use in the standardising condition ; alloy selector switch, which is set to the particular alloy being measured ; and tolerance control, which enables the maximum and minimum tolerance limits to be adjusted.

Refractory Nozzle Blades for Gas Turbines

THE operating temperatures of gas turbines are dependent on the properties of the blade material. Since the advent of the jet engine, immense strides have been made in the improvement of metallic alloys and long-life gas turbines can now be designed to run at temperatures up to about 750° C., but this development is probably nearing its limit. In order to achieve a fuel efficiency comparable with that of a marine diesel engine, the operating temperature will have to be raised to something of the order of 1,200° C., and this will clearly call for cooling of the blades or, alternatively, the use of non-metallic materials.

In turbine rotors the centrifugal field imposes high stresses on the blades, but also enables them to be cooled conveniently by the thermosiphon method, and in this case therefore, the choice is likely to be in favour of cooled metal blades. Conditions are quite different in the case of the fixed blades, however, where the stresses can be kept a good deal lower. Intensive investigation has shown the difficulty and complication of cooling a ring of nozzle blades effectively, and this is an obvious field for the application of non-metallic materials. There is an inherent difficulty in the relatively high brittleness of these materials, and an adequate factor of safety must be built into the design, and designers accustomed to metals must adopt their thinking to utilise the available materials, which at the best are somewhat akin to cast iron (at room temperature) in their behaviour.

Developments in this field over the last eight years were reported in a paper presented recently to the North-

East Coast Institution of Engineers and Shipbuilders by Dr. T. H. Blakeley and Mr. R. J. Darling. The programme of work concerned was undertaken jointly by Pametrada and The Morgan Crucible Co., Ltd., and numerous materials were tested in the laboratory under conditions designed to simulate the stresses and thermal shocks likely to be encountered in service. Various methods of manufacturing the required blade shapes were also investigated, and the shapes themselves were modified to some extent so as to meet the special requirements of the materials. Cascades of blades were tested in a high velocity gas stream at temperatures up to 1,200° C.

The results indicated that stator blades can be made in a ceramic material (zircon), but that their factor of safety is low. Metal-ceramic blades are more promising, but there is a nice balance between good creep resistance and good high temperature strength, on the one hand, and good thermal shock resistance on the other. Further improvements can be expected on the results so far reported. More promising than the materials already discussed are the newer forms of silicon carbide now being developed. These have excellent high temperature strength, and good resistance to oxidation, thermal shock and creep. Fabrication of these bodies still presents difficulties, but the authors are confident that, here again, further improvement can safely be prophesied. Carbon and graphite, with an impervious coating, would be ideal material (apart from their intrinsic brittleness), but the perfect coating has yet to be developed.

In tests to date the holding pieces have given, if anything, more trouble than the blades themselves, and the prevention of gas leakage is a particularly serious problem which must be solved if progress is to continue. The answer here may lie in the use of metallic mountings —possibly protected with a coating of refractory—which could be relatively easily cooled as only a small amount of surface is exposed to the hot gas stream.

Extensions at Thorncliffe

Newton Chambers New Development Department

THROUGHOUT the long history of Newton Chambers & Co., Ltd., Thorncliffe Works, near Sheffield, there is a continuing record of progress and development. Ever since 1793, when George Newton and Thomas Chambers established an iron-foundry in the Thorncliffe valley, the men who successively have been at the head of this undertaking have been far-sighted enough to develop new methods and new products to meet the changing times and to satisfy modern needs.

Newton Chambers were pioneers in the distillation of coal-tar oils which led to the Company's present extensive chemical business; they were in at the beginning of the gas industry, equipping gasworks throughout the country; they have developed modern domestic and industrial heating appliances; and currently they are playing an important part in equipping Britain's expanding steel industry. It is significant, too, that a large scale pilot plant for the hydro-refining of benzoles and naphthas is being built at Thorncliffe, and that the Company is also turning its attention to opportunities arising from the development of the atomic power industry.

With such a background of progress, Newton Chambers have now decided to centralise all their engineering development activities and re-house them in their new Development Department. The building is of portal frame construction with blue vitrolite slab curtain walling between the windows in the exterior walls. These slabs are in air-spaced double panels for insulating purposes.

The chief feature of the building is the main central workshop, in which will be produced and tested prototypes of the various kinds of plant intended for manufacture by Newton Chambers. The workshop is 35 ft. wide and 108 ft. long and has good natural light through clere-storey windows. It is served by a three-ton overhead electrical crane controlled at floor level, and bus-bars throughout the full length of this workshop, with terminal points at every column, provide electrical power up to a capacity of 100 h.p. for driving compressors, fans and other equipment. In the roof, thermocoust slabs have been used, and these are easily removable for the installation of temporary chimneys or other special ventilators. On one side of the workshop there is provision for a line of fitters' benches: the other side is planned to give a number of important working facilities.

On the ground floor there are facilities for the mechanical testing of ferrous and non-ferrous metals, and for experimental work on materials, welding, heat treat-

(*Continued on page 246*)

All-Welded Aluminium Footbridge

Sixty Foot Span at Rogerstone

THE growing use of aluminium as a structural material is well exemplified in a graceful footbridge that has been completed for Northern Aluminium Co., Ltd., over the River Ebbw, between the South Wales towns of Rogerstone and Bassaleg. The bridge, which is of 60 ft. span, is one of the first examples of all-welded fabrication for a structure of this type. Designed from the beginning to take full advantage of the characteristics of aluminium as a structural material, its method of construction reflects much of the experience that has been gained during the last ten years. The bridge, in its turn, serves to add yet more to the engineer's knowledge of light-alloy construction.

The need for this bridge arose when an old-established footpath (a public right-of-way) was re-routed to skirt an area of new playing-fields. The stipulations of local authorities, regarding its approaches and clearance above flood-water level, have influenced its form to some extent. The approaches carrying the pathway were limited to a gradient of no more than 1 in 10, and the bridge was required to have a clearance, above the highest water mark, of 3ft. These conditions meant that, if the approaches were not to be unduly long, the bottom chord of the bridge girders could be no lower than the points of support on each bank, and allowed little depth for bracing.

The bridge is of through-type W-latticed girder construction, the top chord of each girder serving as a handrail. This top chord is curved to a radius of 226 ft., the depth of girder being 4 ft. 6 in. at the ends, and 6 ft. 3 in. at mid-span. The 4 ft. 6 in. wide footway is similarly curved to give a 4 ft. 6 in. handrail height throughout.

Since this type of design does not allow the top chords to be braced to each other, all the essential lateral rigidity is provided by transverse and diagonal bracing, in both horizontal and oblique planes, below the level of the flooring.

The bridge was designed for a live load of 100 lb./sq. ft. (on a 15 lb./sq. ft. dead load), with provision for a point load of 500 lb. Lateral design loadings were 50 lb./ft. run on the handrail, and a wind load of 12lb./sq. ft. (The bridge is in a reasonably sheltered position).

Bulbed and Lipped Extruded Sections

In order to use the structural material to best advantage, maximum use was made of bulbed and lipped extruded sections. These are designed specifically for aluminium, and in them metal is economically disposed remote from the centroid to order to increase flexural and torsional rigidity, and resistance to local buckling.

The bottom chord of each bridge girder is a $4 \times 3 \times \frac{1}{4}$ in. extruded tee, and the top chord and handrail a tee with its flanges radiused and bulbed to provide a comfortable hand-grip. Lattice members are of $3\frac{1}{2} \times 1\frac{3}{4}$ in. lipped channel section, and bracing members of $1\frac{3}{4}$ in. equal bulbed angle. The alloy chosen for all structural parts was Noral B51S (B.S.1476 : HE 30), fully heat treated. In this condition, this alloy has a guaranteed

proof stress of 16 tons/sq. in.; it has a very high resistance to atmospheric attack, and has come to be recognised as the most suitable aluminium alloy for normal structural applications.

Welded Construction

All joints were welded, provision being made to ensure that as far as possible welds ran longitudinally rather than transversely across sections. In welding a heat treated aluminium alloy such as HE30, there is an inevitable local reduction of properties close to the weld, though after welding the quenching effect of the adjacent metal usually brings about a partial recovery of strength, generally to that of the " W " temper (in the case of HE30 alloy, giving a proof stress of 7 tons/sq. in.). By avoiding transverse welds, the local loss of strength can be minimised, and in the case of the footbridge in question the usual practice of making use of gusset plates at joints was also adopted. All welding was carried out with Argonaut shielded-arc equipment.

The flooring consists of Noral corrugated aluminium sheeting of the deep-ridged " Industrial " pattern 14 s.w.g. (0·080 in. thick) with the corrugations placed transversely. The sheets are carried on two longitudinal $3 \times 2 \times \frac{3}{16}$ in. plain angle sections welded to the lattice members, and are secured with aluminium rivets. The footway itself was made by laying about a ton of bituminous road material over the corrugated sheeting.

To reduce the spaces in the girders (to prevent a child, for example, falling through the side of the bridge), five 1 in. diameter aluminium tubes, the full length of the bridge, pass through the lattice members. Each tube is secured by welding only at each end of the bridge (where the handrails turn over the form to end posts), passing through clearance holes in the intermediate members.

The bridge, which was designed for Northern Aluminium Co., Ltd., by Aluminium Laboratories, Geneva was fabricated by the Atlantic Shipbuilding Co., Ltd., at Newport. The complete structure (approximately

2,100 lb. without the bituminous decking) was transported to site by road, and launched with the help of two mobile cranes. At its points of support, the bridge is carried on pin-joints, a link being provided at one end to allow for thermal expansion. When complete, the whole aluminium structure was left in its natural state, without painting or other protection. The fact that no painting is likely to be required during its lifetime was, of course, one of the major factors leading to the choice of aluminium for its construction.

The number of aluminium bridges of any kind in existence is not very considerable, and it is believed that this is among the first to be of all-welded construction. As with any other article, simple economies generally dictate the choice of material for bridge construction, and if aluminium is to be competitive, it must obviously be used in the most efficient way possible. This new footbridge is believed to embody all the latest development in aluminium design and fabrication, and may well be the forerunner of many similar structures.

Heat Treatment of Marine Forgings

Electrically Heated Bogie Hearth Furnace

T. S. FORSTER & SONS, LTD., of Sunderland, have long been specialists in the production of heavy forgings for marine applications. Among the more specialised components which they manufacture are forgings for marine diesel engines. Many of these parts are hardened and tempered, the former operation being carried out in the electrically heated bogie hearth furnace illustrated, which was designed and manufactured by G.W.B. Furnaces, Ltd. For mild steel parts, the furnace is used for normalising only. The furnace is rated at 120 kW. contained in a single automatically controlled zone with the ribbon type heating elements located along the side walls, under the arched roof, and on the inner face of the door. While the maximum temperature of which this furnace is capable is 1,050° C., the normal hardening temperatures generally do not exceed 875° C.

As an example of the heating rate obtained from this unit, during the period 1.15 a.m. to 5.15 a.m. on the day noted, the charge was brought up to temperature from 180° C.–875° C. The insulated bogie is topped with a layer of selected well burnt refractory blocks, and can carry a load of up to 2·5 tons, the effective space within the heating chamber permitting loads up to 7 ft. long × 4 ft. wide × 2 ft. 6 in. high to be carried. Entry and exit of the bogie is effected by an electrically driven mechanism, and a special sealing device is fitted to prevent heat losses from the slight gap between the bogie refractory and the body of the furnace. Sealing troughs filled with sand are raised to contain flanges extending from the underside of the furnace and the bottom perimeter of the bogie, the mechanism being actuated manually by means of the hand wheel seen on the front end.

This installation, by reason of close temperature control, cleanliness of operation and congenial working environment, represents a radical improvement over the working conditions formerly associated with operations of this nature.

Extensions at Thorncliffe

(*Continued from page 244*)

ment, etc. The equipment includes a 100 ton tensile testing machine, a Brinell hardness testing machine, and a Wohler type fatigue machine. A long term programme of work will be undertaken to attempt to correlate results of mechanical tests with evidence of defects by radiography. Inspection equipment includes a Kraut Krammer ultrasonic flaw detector—which will be used for the detection of flaws such as laminations in plate—and a magnetic crack detector. The laboratory has the usual mounting and polishing equipment and the latest Vickers projection microscope. There are also good machine shop facilities and equipment for chemical analysis. Machine tools have been installed for the preparation of test specimens and for the manufacture of small components for prototypes.

On the first floor are the metallographic laboratory and X-ray dark room. These will be used in conjunction with the 300 kV. Solus Schall X-ray unit and the 150 kV. hollow anode unit which have been installed for Class I work on pressure vessels.

The Company specialises in heat exchange equipment, and in addition to the more orthodox types of tubular heat exchangers used in the chemical industry, they have been producing for nearly a quarter of a century recuperators for steelworks.

Much of the early work in the new department will be concentrated on the development of recuperator equipment for high temperatures, and the Company have in mind units which can be used with waste gases up to 1,500–1,600° C. In addition to meeting the needs of the steel industry, it is planned to develop equipment which will improve melting facilities in iron foundries and reduce melting costs.

In charge of the new department is Mr. Edwin Watkinson, M.I.Mech.E., Chief Engineer, Development, who is the current Chairman of the Yorkshire Branch of the Institution of Mechanical Engineers.

NEWS AND ANNOUNCEMENTS

Aluminium in Electrical Engineering

THE use of aluminium for electrical purposes goes back at least half a century, but during the past few years, considerable progress has been made in further expanding the applications of aluminium in this field. A Symposium on Aluminium in Electrical Engineering, organised by the Aluminium Development Association, is to be held at the Institution of Electrical Engineers on Thursday and Friday, May 16th and 17th, 1957, with the object of providing an opportunity for electrical engineers to discuss experience already gained in the use of aluminium in electrical engineering, and also to indicate its future potentialities. The papers to be presented for discussion will be grouped under three main headings, viz. : General and Economic Considerations in Using Aluminium in Electrical Engineering ; Aluminium in Transmission and Distribution Lines ; and Aluminium in Electrical Equipment.

I.E.A. Conference

THIRTY-SEVEN of Britain's leading experts on the techniques of instrumentation, electronics and automation will take part in a seven-day conference in London during May, at which every aspect of these new industries will be reviewed and discussed. The Conference will form an essential part of the Instruments, Electronics and Automation Exhibition at Olympia, and for the purpose of the Conference the field has been sub-divided into a number of sections, a complete day being devoted to each subject. The programme includes Automation Day (May 8th) ; Nuclear Day (May 9th) ; Education Day (May 10th) ; Medical Day (May 13th) ; Industrial Day (May 14th) ; Computer Day (May 15th) ; and Communications and Navigation Day (May 16th). The morning session of each " day " will be devoted to a general review of the subject, whilst more specific techniques and applications will be dealt with in the afternoon.

Analytical Chemistry Congress

A CONGRESS on Modern Analytical Chemistry in Industry, organised by the Scottish Section of the Society for Analytical Chemistry, will be held at St. Andrews University from June 24th–28th, 1957. The papers to be presented will be grouped under three headings, viz : Analysis in Modern Industry ; The Application of Some Newer Analytical Techniques in Industry ; and Developments in Analysis for New Problems in Industry.

It is understood that the conference is already fully subscribed, so that no further registrations are possible. It is hoped, however, that the proceedings may be published in due course.

Vacuum Technology Symposium

THE Fourth Annual Symposium of High Vacuum Technology will be held in Boston, Massachusetts on October 9th–11th, 1957, at the Hotel Somerset. Sponsored by the Committee on Vacuum Techniques, the meeting is expected to attract attendance by operating people, design and process engineers, and research men whose duties involve the use of high vacuum. The Committee on Vacuum Techniques has been formed as a non-profit-making corporation to assist in the dissemination of information on vacuum techniques, processes, and new developments in equipment to academic, government and industrial organisations. Authors with subjects dealing with methods of producing and measuring vacuum, new processes using vacuum, fundamental developments in vacuum technology, and the use of vacuum in research, are invited to contact the Committee at P.O. Box 1282, Boston 9, Massachusetts, U.S.A.

Fulmer Open Day

FULMER RESEARCH INSTITUTE announce that an Open Day (by invitation only) will be held on July 2nd, 1957. This year marks the 10th anniversary of the official opening of the Institute by the late Sir Stafford Cripps. The success of the late Colonel W. C. Devereux's venture in providing confidential research facilities for industry is witnessed by the five-fold increase in the annual expenditure on contracted research.

Aircraft Production Conference Report

A complete report of the Aircraft Production Conference held at the University of Southampton on January, 8th–9th, 1957, will shortly be available in book form. This report will contain the addresses at the opening luncheon, the six papers presented, including the Lord Sempill Paper, together with the subsequent discussions and the summing-up. Copies of the report may be ordered from the Publications Department of the Institute of Production Engineers, 10 Chesterfield Street, London, W.1. The price per copy (including postage) is 7s. 6d. for members of the Institution, and 10s. for non-members.

Special B.I.F. Trains

BRITISH RAILWAYS are making special arrangements for B.I.F. buyers from May 6th–17th. A special train will leave Euston daily at 8.55 a.m., arriving at Castle Bromwich station (adjacent to the Fair) at 11.18 a.m. It will return at 5.10 p.m., arriving Euston 7.48 p.m. Trains from other parts of the country will stop at the Exhibition station and special excursion rates will be available on certain days, from certain specified centres.

Titanium Melting Plant Order

THE Metals Division of Imperial Chemical Industries, Ltd., has ordered through Fleischmann (London), Ltd., arc melting plant for an annual production of about 2,000 tons of double melted titanium ingots. This melting plant will be one of the largest in the world and probably represents the most advanced type. Among other devices it will be equipped with fully automatic, electronically controlled electrode feeder gear and be laid out for remote control. The plant was developed by W. C. Heraeus G.m.b.H. of Hanau, Western Germany, in collaboration with I.C.I., and is at present under construction at Hanau. Heraeus are suppliers of vacuum arc melting furnaces to practically all European manufacturers and atomic energy authorities as well as various overseas firms. It is believed that this type of furnace will, in the near future, assume increasing importance for melting special steels.

Steel Plate Import Duty Suspension

UNDER the Import Duties (Exemptions) (No. 15) Order, 1956, the import duties on a wide range of iron and steel products, including almost all plates, are suspended until September 18th, 1957. After consultation with the Iron and Steel Board about the supply position, Her Majesty's Government have decided to prolong until March 18th, 1958, the suspension of import duty on such plates. A new Order, the Import Duties (Exemptions) (No. 4) Order, 1957, (S.I. No. 503) has been made, and will come into operation on September 19th, 1957. Copies of the Order may be obtained from Her Majesty's Stationery Office or from any bookseller, price 3d. (by post 5d.). The question of further suspension of import duty on other iron and steel products is being examined; an announcement in respect of the duties on these other products will be made in due course.

Automatic Production Conference

THE exceptional amount of interest aroused by the Institution of Production Engineers Conference on The "Automatic Factory" at Margate in 1955—interest which has been gaining in intensity ever since—makes another Conference on the subject imperative. Accordingly, the Institution is holding a Conference at Harrogate, from June 30th to July 3rd, 1957, with the theme "Automatic Production—Change and Control." The Conference is open to all interested in the advancement of technology or management: further particulars can be obtained from the Secretary, The Institution of Production Engineers, 10 Chesterfield Street, London, W.1.

International Cybernetic Association

AT the successful first International Cybernetic Congress, held at Namur from June 26th to 29th, 1956, it was decided to form an International Cybernetic Association. The latter was founded in January of this year, and now numbers more than 1,000 members (of which 300 are industrial firms), representing 26 countries.

The Association aims at securing a permanent and organised liaison among workers carrying out research on the various aspects of the subject, and at the development of this science and its technical application. Further information can be obtained from the permanent Secretariat of the Association at 13 Rue Basse-Marcelle, Namur, Belgium.

Technical Writing Symposium

THE Metals Division is to hold a Symposium on The Technical Writer and the Special Librarian on May 27th, 1957, at the Hotel Statler, Boston, Mass., as part of the Special Libraries Association Annual Convention. Subjects to be discussed include the growth of the technical writing profession; library aids to technical writing; ways in which the technical writer can help the librarian; and the relationship of technical writing and library functions.

Sintox Cutting Tools Agreement

AN agreement has recently been made between Lodge Plugs, Ltd., who manufacture Sintox material at their works in Rugby, and English Steel Tool Corporation, Ltd., Openshaw, Manchester (a wholly owned subsidiary of English Steel Corporation, Ltd., Sheffield), whereby the distribution of Sintox cutting tools in the United Kindgom is now to be undertaken exclusively by English Steel Tool Corporation, Ltd. A period of intensive research has preceded this development and English Steel Tool Corporation, Ltd., now have a team of trained technicians to assist and advise customers in the application of this remarkable cutting medium. Literature and price lists will be supplied on request.

Steel Prices

NEW maximum prices for nickel- and vanadium-bearing steels came into force at the beginning of April to cover the higher cost of these alloying materials. Examples of changes in the basis price per ton of black bars are: austenitic steel increased from £283 to £293; En. 10 (¾% nickel) increased from £64 13s. 9d. to £65 10s. 3d.; and En. 27 (3–3¾% nickel) increased from £100 13s. 9d. to £104 11s. 6d.

Automatic Measurement Conference

THE Society of Instrument Technology is holding a Conference at University College, Swansea, from September 23rd to 26th, 1957, on Automatic Measurement of Quality in Process Plants. The main object of the gathering is to provide an opportunity for the users and makers of automatic measuring equipment to meet and discuss their work. Among topics which it is hoped to cover are chromatography, mass spectrography, *p*H measurement, spectroscopy, titration, density, moisture content, refractive index, and viscosity and "consistency."

Additional Mond Nickel Fellowship for 1956

MR. G. F. C. du PLESSIS (South African Iron and Steel Industrial Corporation Ltd., Pretoria, South Africa) has been awarded a 1956 Mond Nickel Fellowship, to enable him to study the preparation of ores by sintering, pelletizing, etc., and the effect on blast furnace practice of the use of prepared burdens.

Industrial Films

THE Central Office of Information have recently issued a list embodying all those films in the Central Film Library's "Films for Industry" catalogue which are available on loan from the Library free of charge. The "Films for Industry" catalogue and supplement, containing details of 693 films and 57 filmstrips, is obtainable from the Central Film Library, Government Building, Bromyard Avenue, Acton, London, W.3, price 2s. post free.

Slab Casting Machine Order

SHEPPARD & SONS, LTD., of Bridgend, have received a further order for a £12,000 zinc slab casting machine from Société des Mines et Fonderies de Zinc de la Vieulle Montagne for their plant at Vieulle Montagne, Balen Nethe, near Antwerp. This order follows on successful business recently concluded in the North American continent. The Company have plans in hand for expansion, the first phase of which provides for large heavy fitting and erecting shops. It is expected that these additional facilities will come into production during the autumn of this year.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Fume Cupboard Fans

THE method of protecting fans against corrosive gases by a coating of polythene, developed by Woods of Colchester, Ltd., is now applied to Aerofoil fans designed for fume cupboards. As for other applications, the axial flow design has advantages for fume cupboard extraction. Inserted directly into straight ducting, it enables exhaust systems to be kept simple and compact.

The new fume cupboard fans, made in three sizes, 6 in., 7½ in. and 9½ in. diameter, are completely protected with polythene, inside and out. The motor and casing are hermetically sealed in a covering which is resistant to practically all corrosive reagents. To ensure adhesion of the polythene to the fan, the casing is made from perforated steel and is coated on both sides. Thus polythene passes through the perforations, joining the inner and outer coatings, and as a result the metal is sheathed within a homogeneous double skin.

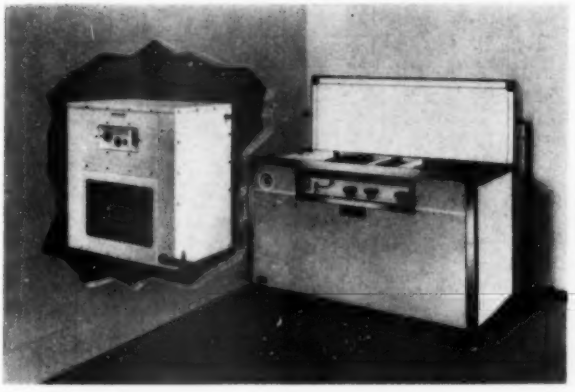
The fan impellers are phenolic mouldings, inherently resistant to corrosion, and the hubs are designed to shield against the ingress of fumes into the motor through the spindle bore. The motors are fitted with a " breathing " tube which passes through the casing, giving access to clean air. The two smaller fans are driven by a new two-pole shaded-pole motor developed by Woods, and the largest size by a capacitor motor. The lubricators are extended to the outside of the casing, and the fans are connected to the electrical supply by leads, 3 ft. in length, taken out through a hole in the casing which is sealed with polythene. Supporting studs with polythene caps are provided on the casing for carrying the fan on brackets. Connectors moulded in Neoprene are supplied for connecting the fan to the fume cupboard and to ducting.

Woods of Colchester, Ltd., Braiswick Works, Colchester.

Cooling Photographic Solutions

IN tropical and subtropical countries, it is often necessary to cool chemical solutions in order to obtain the correct processing temperature. Kodak, Ltd., in conjunction with Frigidaire, Ltd., have therefore made available to special order Kodak processing units, Models 56, 54 and 30 complete with water jacket cooling units, which are specially designed for use in the tropics.

The compact, small-capacity cooling unit comprises a Frigidaire air-cooled, hermetically sealed, rotary compressor condensing unit, suitable for A.C. supply only. Cooling of the water jacket in the processing unit is effected by means of two sets of direct expansion coils which lead from the cooling unit into the water jacket in front of and behind the inner processing tanks. It is claimed that this unit will maintain the processing solutions at a temperature of 68° F. in room temperatures up to approximately 90° F. An adjustable thermostat is provided. The cooling unit is housed in a ventilated stoved-enamel sheet metal cover. If required, a stainless steel or vitreous enamelled cover can be supplied at extra cost. The cooling unit is not available as a separate



item, but is supplied as a complete assembly with the processing unit.

The cooling unit is designed to control the temperature of the processing solutions only, and does not control the temperature of the wash water, so it is only suitable for use where the temperature of the wash water does not exceed 80° F. Where the wash water is considerably in excess of this temperature, it is recommended that the Frigidaire cabinet cooling plant in conjunction with a Kodak processing unit Model 56 should be used. This plant (which can be situated outside the darkroom) is entirely automatic and is designed to cool 25 gallons of water per hour from an initial temperature of 90° F. to a final temperature of 68° F. By this means, not only is the water jacket with its contents maintained at the standard temperature, but the wash water is also cooled. This plant is only suitable for use with a specially modified Kodak processing unit Model 56.

Kodak, Ltd., Kodak House, Kingsway, London, W.C.2

Electric Motors

ENGLISH ELECTRIC has recently introduced a new range, known as Class C, of axially ventilated electric motors covering ¼ h.p. to 50 h.p. ratings. These motors have standard fixing dimensions to the new British Standards draft specification CW (ELE) 6246; they use Class E insulation, which permits a temperature rise of 65° C. on 40° C. ambient temperature; and they are thus smaller, lighter and cheaper machines. The new motors will supersede previous designs of ventilated machines which permitted only a 40° C. rise.

The electrical insulation used in the Class C motors is intended to withstand a total temperature of 120° C. The conductor wire is covered with an enamel based on polyvinyl-acetal resin, a material which has been proved in service for many years. The coils are mush wound and are enclosed in the core slots by a liner comprising a combination of a cellulose tri-acetate film and press-paper, the press-paper forming the mechanical support for the film. The slot is sealed off with a channel formed from a similar combination material, but which utilises

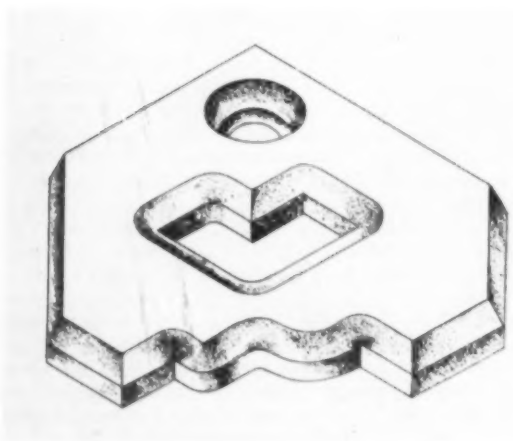
leatheroid as the backing to ensure maximum stiffness for the narrow channel. An additional seal on the larger machines is provided in the form of a wedge of phenolic laminated board. The coils are separated in the slot by a channel section of a similar material to the slot seal.

On the overhand, the insulation between phases is a pad of varnished Terylene cloth. The coil lead insulation is a braided Terylene sleeve which has been heat treated, producing a tough and very closely braided sleeve. The sleeve over the coil joints is of braided glass. The terminal leads are of polychloroprene covered cable, these leads being brazed to the overhand with Terylene tape. The whole stator core is impregnated in an oil-modified phenolic varnish, giving good protection against humid conditions and bonding the whole windings into a hard mass.

English Electric Co. Ltd., Marconi House, Strand, London, W.C.2.

Gas Cutting Bevels

A RECENTLY published British patent (No. 761,454), relates to an essential feature of the British Oxygen Company's Beagle transportable, cross-carriage, oxygen profile cutting machine. The Beagle is a small light-weight, electrically-driven cutting machine with a maximum cutting thickness of 2 in., and a useful working area of 6 ft. × 2 ft. 6 in. The bed may, however be extended by increments of 6 ft.



The patent relates to a novel feature of the machine, which is the profile bevelling attachment. This automatically maintains any set angle of bevel, irrespective of the shape of the profile being cut. The attachment consists of a tracer wheel assembly and a cutter head, both being mounted for rotation about their respective vertical axes, and mechanically interlocked so that the bevel angle, once set, is maintained throughout all movements initiated by the tracer wheel assembly. The cutting nozzle may be set to produce any bevel up to 45°.

The British Oxygen Co., Ltd., Bridgewater House, Cleveland Row, St. James's, London, S.W.1.

Dry Powder Fire Extinguisher

A NEW, easily operated dry powder fire extinguisher, is announced today by Nu-Swift, Ltd. By striking a knob, a cloud of fine powder is shot out under pressure and smothers flames quickly and efficiently. The new extinguisher has been specifically designed to combat fires long rated the most dangerous of all—those on inflammable liquids of all types, including alcohols and industrial solvents and electrical equipment. Tests have shown that in the hands of an inexperienced operator the dry powder extinguisher will quell a petrol fire 9 sq. ft. in area. Comparative figures are: 2-gal. air foam extinguisher, 8 sq. ft.; 2-gal. chemical foam, 6 sq. ft.; 10 lb. CO_2, 6 sq. ft.; one quart auto chlorobromomethane, 3 sq. ft.; one quart auto C.T.C., 1 sq. ft.; one quart C.T.C. pump, 0·5 sq. ft. With an experienced operator the efficiency quotient rises by approximately 50% so that for the dry powder extinguisher it reaches a total of 14 sq. ft.

The high extinguishing capacity is due to the nature and preparation of the dry powder, combined with the method whereby it is expelled, so that an excess of powder in any part of the cloud is avoided. The dry powder consists of a number of chemicals, the principal being sodium bicarbonate. It is held, with dried carbon dioxide, in a sealed pressure charge, so that it cannot be affected by atmospheric humidity. Scientific preparation, mixing, grinding, sieving and drying ensure that all particles are regular in shape and size, and electrostatic coagulation is prevented by special treatment during manufacture; ingredients liable to bacteriological spoilage are not used.

Amazingly compact, the Nu-Swift extinguisher, which is designated Model 1604, is only 15⅞ in. high and weighs 10½ lb. A pressure gauge is fitted so that at a glance a user can confirm that the extinguisher is charged and ready for action. A strong rubber carrying handle, shaped like a pistol grip, makes it possible to aim accurately at the heart of a blaze, even in the dark.

Nu-Swift, Ltd., Elland, Yorks.

Temperature Recorder/Controller

A NEW version of the Fielden electronic resistance thermometer has just been introduced for the recording, control, and indication of industrial temperatures. The original models have been evaluated in industry during the past eighteen months, and the instruments now available include many special features which result in outstanding performances and reliability.

The new range of self-balancing recorder/controllers has been designed for the measurement of industrial or laboratory temperatures giving potentiometric accuracy reproducible to approximately 0·2% full scale. They can be supplied for any range span greater than 20° C., between −200° C. and +500° C., as single point recorders and as four point recorders. An additional 11 in. dia. indicating scale can also be fitted to the single point model.

The ample servo-power available overcomes friction and provides the torque to operate electrical on/off controllers or pneumatic controllers. To ease the usual problem of routine maintenance and service, the complete electronic chassis is not calibrated. It is plugged into the main assembly and all chassis are completely interchangeable.

The bridge circuit employed is fed with A.C. voltage and there is, therefore, no stabilised D.C. source required, nor is there any need for recalibration or standardisation when the instrument is in use. The

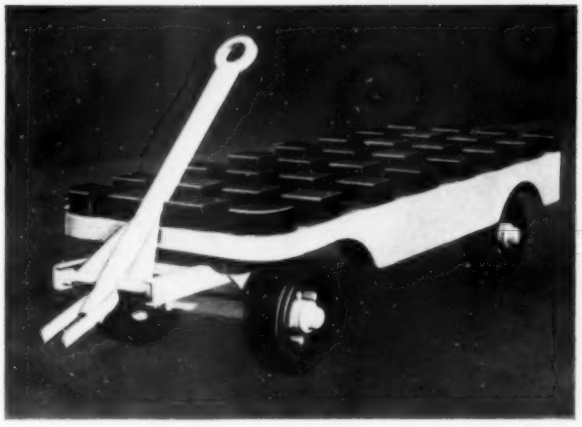
simple, plug-in-type electronic chassis can easily be changed if required, and again, there is no need for recalibration. The resistance elements used are platinum resistance bulbs with exceptionally good stability and these are fully interchangeable in the majority of ranges. A comprehensive range of chart speeds and standard temperature scales are readily available.

Fielden Electronics, Ltd., Wythenshawe, Manchester, 22

Four Wheel Industrial Trailer

Wessex Industries (Poole), Ltd., have recently supplied a number of heavy 6-ton four-wheel industrial low-load trailers to John Summers & Sons, Ltd., for use in handling and transporting steel plates in their works.

The specification follows the standard type, Model 62, i.e.: all steel channel chassis and framework; steel plate platform (8 ft. × 4 ft. and 12 ft. × 4 ft.); and all electrically welded steel plate skirt. The platform is

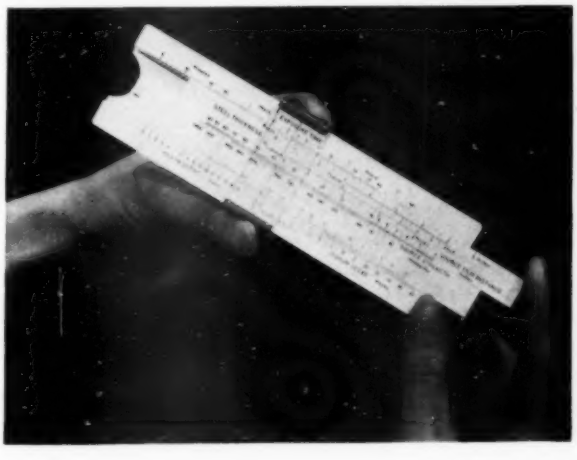


mounted on heavy steel axles with turntable steering, and the heavy tubular towbar (with eye hitch) is fitted with a stop to prevent the towbar from falling to the ground. The trailer is equipped with 15 × 6–11¾ industrial solid rubber tyred steel wheels, on five stud taper roller bearing hubs. Welded to the deck are rows of "stools" on which the steel plate load is placed flat. Chains or slings can then pass underneath the load, between the "stools," thus enabling the load to be easily removed.

Wessex Industries (Poole), Ltd., Dolphin Works, West Street, Poole, Dorset.

Gamma-Radiography Exposure Time Calculator

The British Steel Castings Research Association announce that modifications have been made to the iridium scale of the slide rule which they supply for the calculation of exposure times in gamma radiography. The change has been made necessary by the decision of the Isotope Division of the Atomic Energy Research Establishment to revise the calibration figures for iridium sources which they supply. As from January 1, 1957 these sources are being rated at 54% of their previous value in millicuries. New slide rules embodying the revised iridium scale are now available from the Association at East



Bank Road, Sheffield, 2, and existing users of the calculator can have a corrected slide fitted on payment of a small charge.

The British Steel Castings Research Association, East Bank Road, Sheffield, 2.

Carbon Ejectors

THE universal suitability of carbon for handling all types of corrosive liquids has led to the development of carbon ejectors or siphons for emptying tanks of pickling liquor and similar corrosive fluids. Pickle tanks are generally situated below ground level, or are not provided with side

outlets, so that the acid must be emptied from the top of the vessel by means of a pump or ejector. Tanks are usually emptied at intervals, such as weekly or monthly, and a pump, if fitted, would only operate for very short periods with long intervals of idleness. This is wasteful and costly, since a pump suitable for handling dirty pickling liquor is unlikely to be adaptable to another duty.

Powell Duffryn Carbon Products, Ltd., now offer a range of carbon ejectors of both water-operated and steam-operated types. These ejectors are capable of handling all corrosive fluids, and particularly waste pickling liquors heavily contaminated with crystals, shale, etc., at high discharge rates. With the water-operated types, low pressure water is suitable and waste liquor can be discharged directly to the neutralisation plant or to waste. The ejectors are exceptionally robust, both mechanically and thermally. There are no moving parts and all carbon parts are completely protected by the cast iron casing.

Powell Duffryn Carbon Products, Ltd., Springfield Road, Hayes, Middlesex.

Extinguisher For Metal Fires

A NEW special-purpose fire extinguisher is now being marketed to meet the exceptionally difficult problems associated with fire outbreaks involving metals such as sodium and calcium, or magnesium and aluminium in the form of powder or swarf. Manufactured by The Pyrene Co., Ltd., the new extinguisher, Model PDMU 25, is charged with 25 lb. of dry chemical powder which is discharged under pressure provided by a cartridge of carbon dioxide gas. The dry chemical powder is applied to the burning metal by means of a specially-designed applicator comprising a long tubular metal extension terminating in a cone-shaped spreader. The applicator ensures that the discharge of dry chemical powder is delivered lightly on to the fire, in order to avoid the danger of scattering which is associated with this class of

fire. Speedy operation is effected by removing the safety clip, detaching the applicator and striking the top of the extinguisher. A "squeeze-grip" control valve enables the flow of dry chemical powder to be shut off at will, and to be used to its fullest advantage.

The Pyrene Co., Ltd., 9, Grosvenor Gardens, London, S.W.1.

Green Fluorescent Indicator Lamp

THE first miniature fluorescent indicator lamp produced in this country in colour, is now being marketed by Hivac, Ltd., of South Ruislip. The lamps are designed to meet the growing demand for an alternative colour to the standard neon. At present they are only being produced in green but other colours may possibly become available in the future.

Having the advantage of a negligible power consumption and absence of heat, they have numerous applications both in industry and the domestic appliance field. Special uses include mimic diagrams and control panels, exhibition and display signs, as well as process control and other electronic equipment. The lamps are independent of transformer windings, or special low-tension supplies, and can be run continuously, or rapidly flashed, without risk of sudden failure.

Hivac, Ltd., Stonefield Way, South Ruislip.

CURRENT LITERATURE

Book Notices

APPLIED STRENGTH OF MATERIALS

By. A. Jenson. 343 pp. including index. McGraw-Hill Book Company, Inc. 43s. ($5.75.)

WITH so many good books on strength of materials already on the market, an author's task in introducing another one is made very difficult. A new book should either extend the present range of knowledge on the subject or, alternatively, present in an extended or different form a limited part of the subject which has been chosen to cover certain requirements. Professor Jenson's book comes in the latter category.

Most of the syllabus for first year strength of materials taught at universities is covered, and the subject matter is presented in a clear manner. Emphasis is placed on the actual design of structural members and the methods of manufacture, and the properties of various engineering materials, including concrete and wood, are listed. The use of calculus is deliberately avoided when developing all the design formulæ used in the text. Four appendices have, however, been added, which derive centroids of area, moments of inertia, the laws of beam diagrams and flexure formulæ by the usual methods involving calculus.

Professor Jenson appears to deal with strength of materials from the point of view of the architect or building student who wishes to be able to obtain a grasp of the principles of elementary strength of materials, and who does not possess a knowledge of calculus. With the increasing tendency to commence calculus before leaving school, this may be a doubtful advantage, as few students start strength of materials without a knowledge of this branch of mathematics.

" Applied Strength of Materials " is a useful addition to the present range of text books and is of value to all engineers and students, particularly those engaged in municipal engineering.

K.G.H.

INDUCTION AND DIELECTRIC HEATING

190 pp., 154 illustrations. Published by the British Electrical Development Association, 2 Savoy Hill, London, W.C.2. 8s. 6d. (Postage 6d.)

THIS volume is the sixth in the " Electricity and Productivity " series of books published by the British Electrical Development Association. It has been written for both technical and non-technical management executives, and will remove much of the mystery which surrounds modern methods of electrical induction and dielectric heating, and show their essential simplicity from the production engineer's point of view.

Early in the history of electricity two discoveries were made. Experimenters found that when a conductor carrying an alternating current of electricity surrounded a core of magnetic material, it caused the material to get hot. They also found that heat was produced in non-conductors of electricity when subjected to the forces of an alternating current field.

Later, when A.C. became a factor in the industrial and commercial development of electric power, designers of electrical equipment had to allow for the phenomena which caused unwanted but unavoidable losses of energy. To-day, practical knowledge of the effects of those phenomena has formed the basis of new heating processes —processes by which heat may be imparted to an object in definite and controllable amounts, just where and how it is wanted.

The book contains chapters dealing with : induction melting of metals ; induction heating for metallurgical purposes ; mains frequency heating ; surface hardening by high frequency ; surface hardening—general and light engineering applications ; through heating ; annealing and tempering ; brazing, soldering and welding ; dielectric heating ; dielectric heating for plastics ; and dielectric heating in woodworking.

The book indicates how vital a part electricity plays in a wide range of new processes ; how, with the aid of dielectric heating, new uses of synthetic materials have revolutionised the conception and design of many articles in everyday use ; and how the adoption of well chosen applications of induction heating or dielectric heating results in better factory conditions, improves the product, and increases productivity.

Trade Publications

THE use of aluminium has increased more in road transport than in any other single application of the metal, and the March issue of *The Aluminium Courier*, published by the Aluminium Development Association, is mainly concerned with this field. One of the principal articles deals with components for vehicle structures, many of which depend for their complexity of shape on the facility with which extruded sections can be produced in aluminium alloys. A more general article is illustrated by examples of the applications of aluminium in such varied vehicles as meat transporters, refrigerated vans, petrol tankers and bulk cement lorries.

CLEAN air is rapidly becoming considered as essential to the welfare of mankind as pure food and water. An illustrated catalogue recently issued by the Electronics Division of Harris Engineering Co., Ltd., is concerned with Trion electronic air filters, with which it is claimed that particles less than 0·001 micron in size can be removed (the smallest visible particle is about 10 micron in diameter).

LAST October Dr. Howard Biers of the Union Carbide and Carbon Corporation addressed the Annual Meeting of the Stainless Steel Fabricator's Association of Great Britain on the subject of " New Uses for Stainless Steels." The February issue of Bemco *Stainless Steel Review* has been changed in form to accommodate a reprint of an article based on Dr. Biers' talk, which was subsequently published in *Sheet Metal Industries*.

THE Control and Electronics Department of the English Electric Company have recently issued a loose-leaf booklet entitled " Radio Frequency Induction Heating Applications Bulletin." The first part of the booklet contains general information on the possibilities of improved production techniques made available by this form of heating. Loose-leaf sheets giving detailed information of particular applications will be issued from

time to time for inclusion in the booklet, and these will form the second part.

In the search by the metallurgists of J. Stone & Co. (Charlton), Ltd., for a better material for cast marine propellers, which would not only have the required physical properties but also be castable with reasonable facility into complex forms, a series of copper alloys was developed containing substantial proportions (10–15%) of manganese. Aluminium is the other principal alloying element, and nickel and iron are minor but, nevertheless, important constituents. These alloys have been given the generic term "Superston" and are available in the form of castings, plate, sheet, extrusions, rolled bar, drawn wire and tube, in sizes previously regarded as impracticable for materials of similar strength. A new brochure issued by the company gives particulars of the properties, fabrication and applications of this range of alloys.

Rotary hearth and vertical conveyor furnaces are among the types dealt with in an article on continuous furnaces in restricted spaces which appears in the March issue of the *Wild-Barfield Heat-Treatment Journal*. Other principal articles deal with the Spekker photo-electric absorptiometer—its use and abuse—and a thermocouple for high temperatures.

We have received from New Metals & Chemicals, Ltd., a leaflet describing the advantages to be gained by the use of Tetrabor sticks for dressing, grinding and cutting wheels. These sticks consist of sintered boron carbide, which is second only to the diamond in hardness, and comparatively inexpensive.

One of the principal articles in the April, 1957, issue of the *Instrument Engineer*, published by George Kent, Ltd., deals with the characteristics of the Dall flow tube, a primary flow-metering device which has been in use in this country for some time. One of its principal features is a very high metering differential in comparison with the head loss engendered. Other articles are concerned with the reduction of waste in water supplies, the automatic control of a cyclone-fired boiler, chemical cleaning of water meters and the history of flow measurement by differential pressure.

Courtney, Pope (electrical), Ltd., have recently issued a new price list and catalogue giving particulars of some of their lighting fittings. The design and manufacture of special fittings to meet specific conditions forms an integral part of the company's business, and the illustrations will provide an excellent guide to modern trends. Besides neon signs and cold cathode lighting, fluorescent fittings, special ceiling fittings and tungsten fittings are detailed and illustrated.

As usual, the February, 1957, issue of *Foseco Foundry Practice* includes the results of an investigation carried out by the service personnel of Foundry Services, Ltd., and in this particular case the subject is "Casting Cracks in Gunmetal Fittings." Other features deal with cupola charging, degassing of aluminium and its alloys and improved running systems.

A useful 28-page reference book on the electrochemical deposition of metals has been published by Fescol, Ltd. (North Road, London, N.7), as part of a comprehensive folder of information which is being sent to customers and potential customers. The book includes a detailed technical section devoted to the properties of nickel and chromium, including their resistance to corrosion. Although the Fescol process was originally developed to make good deficiencies caused by wear and tear, or incorrect machining, it is now being employed mainly for new components, as it enables new products which have a comparatively cheap and easily worked base to be improved by depositing electrochemically a surface which possesses certain special qualities such as resistance to oxidation, abrasion, etc. The folder contains a series of five leaflets dealing, respectively with the application of the Fescol process to hydraulic machinery; the metal industries; the paper and printing trades; machine shop production; and the textile industry.

Considerable progress has been made in recent years in the manufacture of Portland cement; progress which has been considerably helped by the development of suitable refractories, especially for the clinkering or hot zone. A new booklet, published by General Refractories, Ltd., details a complete range of refractories for this purpose.

"Alumina from Jamaica" is the title of a four-page Fact Sheet designed to give a short, concise account of the activities of Aluminium, Ltd.'s fully-owned subsidiary in Jamaica, Alumina Jamaica, Ltd. This Company mines bauxite, and processes this ore into alumina on the island. The alumina is then shipped to the Company's smelters at Kitimat, British Columbia and to other markets overseas. This Fact Sheet is the third of a series describing Aluminium, Ltd.'s facilities, the earlier ones being the "Kitimat Aluminium Project" and "Aluminium from Canada."

A new four-page folder, uniform in size and format with the previously issued "List of 'dag' Dispersions," has just been published by Acheson Colloids, Ltd. This companion piece of literature lists alphabetically scores of applications for 'dag' products, and refers briefly to their advantages in each case. The information is given in three sections dealing with: 'dag' dispersions as production lubricants; their use in manufactured products; and their use as maintenance and operational lubricants.

Books Received

"Rectifying Semi-Conductor Contacts." By H. K. Henisch. (The International Series of Monographs on Physics). 372 pp. inc. index. Oxford, 1957. Clarendon Press. 70s. net.

"The Chemistry of the Co-ordination Compounds." Edited by J. C. Bailar, Jr. 834 pp. inc. index. New York and London, 1956. Reinhold Publishing Corporation and Chapman & Hall, Ltd. 148s. net.

"Réduction des Minerais de Fer." By R. Durrer. Translated by M. Auxenfans. Preface by M. Malcor. 152 pp. Paris, 1957. Dunod. 1680 F.

"Précis de Magnétoscopie." By E. A. W. Müller. Translated by V. Husarek. Preface by R. Castro. 170 pp. Paris, 1957. 1880 F.

"Stress Corrosion Cracking and Embrittlement." Edited by W. D. Robertson. A Symposium arranged by the Corrosion Division of the Electrochemical Society, Boston, October 1954. 202 pp. New York and London, 1956. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 60s. net.

LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

MAY, 1957. Vol. LV, No. 331

Graphite Resistor High Temperature Furnace

G.E.C. Installation at B.S.A.

GRAPHITE resistor furnaces capable of providing temperatures up to 3,000° C. have been developed by the General Electric Co. Ltd., to meet the demand created by development work on atomic energy, guided missiles, and supersonic aircraft, for high temperatures required in the heat treatment of the new metals—titanium, tantalum and zirconium; for sintering; and for brazing components which will operate at elevated temperatures.

One of the first of these new high temperature furnaces has been installed in the B.S.A. Group Research Powder Metallurgy Laboratory at Small Heath, Birmingham. Designed to give temperatures up to about 2,000° C. and to maintain a good vacuum for the protection of a charge from oxidation, it is to be used for sintering materials for use at high temperatures.

Water-cooled Body

The body of the furnace is a water-cooled, vertical, cylindrical steel tank with a hinged, domed lid. A vacuum-tight seal is formed between flanges on the lid and the furnace body. The charge is heated by radiation from a triangular-shaped assembly of graphite bars which surrounds the charge space. These graphite bars operate at a low voltage supplied by a three-phase transformer. A voltage regulator enables the secondary voltage of this transformer to be steplessly varied to give control over the heating rate.

Radiation screens consisting of molybdenum sheets so arranged as to enclose the heating chamber, provide the thermal insulation. With the furnace lid raised the top radiation screen can be lifted to give access to the chamber. The charge is supported on a graphite tripod.

Vacuum Pumping System

The vacuum pumping system consists of a gas ballast pump, a combined booster and oil diffusion pump, and a valve block which controls the evacuation of the furnace chamber. The valve block is fitted with a five-position operating lever which can be moved only in one direction, to ensure the right sequence of operations. With the lever in position one, air is allowed into the furnace chamber and the pumps can be switched on. In position two, the chamber pressure is reduced by the coarse pump, and this evacuation continues in lever position three—similar to lever position one except that air is not allowed into the chamber—until the pressure has been reduced to 0·05 mm. mercury. With the lever in position four, the diffusion pump continues the evacuation until the required pressure is reached. An operating vacuum

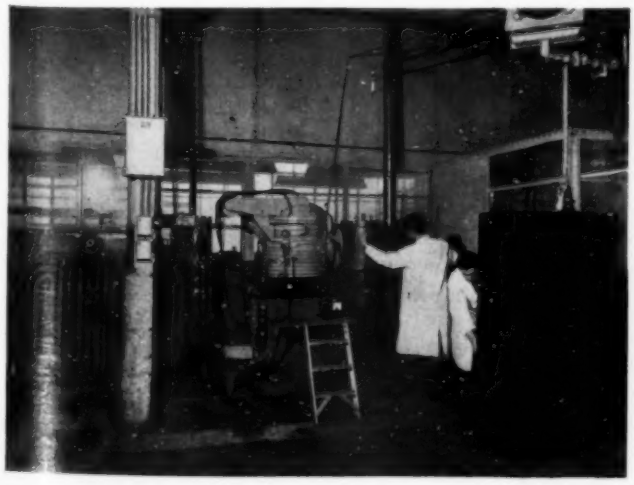


Fig 1.—View of the high temperature vacuum furnace installed in the B.S.A. Group Research Powder Metallurgy Laboratory, showing: (left) transformer; (centre) furnace; (right) pumping system; (extreme right) control panel.

Fig 2. (right)—The top radiation screen being placed in position.

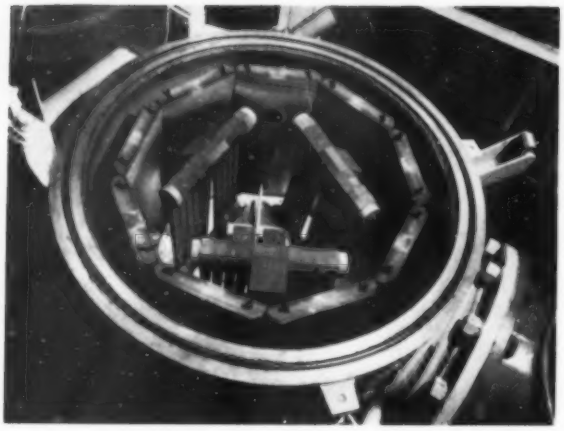


Fig. 4.—View showing the element assembly and side radiation screens.

between 10^{-4} mm. and 10^{-5} mm. mercury can be obtained. When the lever is in position five, all valves are closed so that the furnace chamber is isolated from the pumping system, and leak-rate tests can be made.

Safety devices give protection of both the furnace and the charge against possible failures in the electric and water supplies. Warning of an electric supply failure is given by an audible alarm. In the event of a fault occurring in the water cooling system flow, relays cause an interruption in the power supply to the furnace. An indicator lamp in each cooling circuit simplifies location of a fault.

Maximum rating of the furnace is 120 kVA. The furnace will take a charge approximately 9 in. diameter and 12 in. high with a maximum weight of 90 lb. With an alternate element arrangement the charge space can be increased to 11 in. diameter by 11 in. high. Provision is made for introducing a hydrogen atmosphere into the furnace chamber to hasten the later stages of cooling. In this way, when using the furnace for brazing, a 50% reduction in cooling time can be obtained. G.E.C. furnaces of the same design are made with loading dimensions 4 in. diameter by 6 in. high (for laboratory use) and 15 in. diameter by 24 in. high.

Rapid Determination of Carbon, Phosphorus and Sulphur

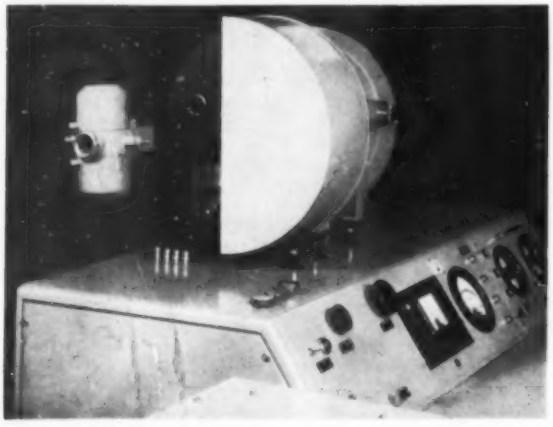
With the development of the new Fluorite Polychromator, Hilger and Watts have provided a solution to one of the most intractable of industrial spectrographic problems, namely the rapid determination of carbon, phosphorus and sulphur in steels.

Spectrographic analysis of carbon, phosphorus and sulphur in steels is troublesome in the near ultra-violet and visible regions. The new Hilger Fluorite Polychromator overcomes these difficulties by making use of resonance lines of the elements in the far ultra-violet or Schumann region—the region of the shortest wavelengths so far exploited with a commercial instrument.

The instrument is a three prism spectrograph in a drum-like container only 18 in. in diameter. It is mounted on a cabinet holding the necessary vacuum apparatus and the measurement and control equipment. The four detectors—one for each element and one for the internal standard—are E.M.I. quartz-window photomultipliers. The specimen is mounted in a spark chamber through which an inert gas is circulated. It is designed so that samples can easily be changed.

TABLE I

Element	Content (%)	Standard Deviation (%)	Sample
Carbon	0·003	0·0007	Rods
	0·01	0·001	Rods
	0·005	0·0015	Flats
	0·06	0·008	Flats
	0·7	0·012	Flats
Phosphorus	0·01	0·002	Rods
	0·06	0·0025	Rods
	0·016	0·0015	Flats
	0·05	0·004	Flats
Sulphur	0·003	0·001	Rods
	0·02	0·002	Rods
	0·02	0·004	Flats



View of the equipment showing the semi-circular housing of the photo-multiplier assembly and the sparking chamber for the samples.

The time required for an analysis, from the moment when the prepared sample is put in the spark chamber to the instant when the contents of all three elements are known, may be less than two minutes. If the carbon content is under 0·05%, a single sparking suffices for all three elements, and the analysis is completed in less than two minutes. If there is more than 0·05% carbon, it is preferable to determine the carbon separately, with different source conditions, but the time taken for a complete analysis is still no more than three minutes. If carbon alone is to be determined the time required is about one minute.

The degree of accuracy achieved can be judged from the figures in Table I, for the results of determinations made on steels supplied by the British Iron and Steel Research Association, the Max Planck Institute for Steel Research, and a number of steel producers.

The Blackman Export Co., Ltd., in which, Keith Blackman, Ltd., had acquired a controlling interest, has now become a wholly owned subsidiary of the latter.

The Dissolution of Tungsten in Mixtures of Hydrofluoric and Nitric Acids

By D. Robbins

Siemens Lamp Works, Preston

The solubility of tungsten in mixtures of hydrofluoric and nitric acids has been investigated. It is shown that the metal is most readily dissolved by a mixture containing approximately 40% by volume concentrated nitric acid and approximately 60% by volume concentrated hydrofluoric acid. The metal surface is oxidised by nitrogen dioxide, the oxide produced being soluble in hydrofluoric acid, but insoluble in other mineral acids.

IT has been recognised since the first isolation of tungsten by Elhuyar[1] that the metal is particularly resistant to attack by acids.[2] It is not attacked by cold dilute or concentrated hydrochloric, hydrofluoric or sulphuric acids, and only slightly attacked when the liquids are heated. Dilute nitric acid produces a protective oxide film on the metal surface, but hot or cold concentrated nitric acid has no action. Mixtures of hydrochloric and nitric acids and of sulphuric and nitric acids have little, if any, action on the metal.

Ammoniacal cupric hydroxide[3] and an oxalic acid—hydrogen peroxide mixture[4] have been proposed as solvents for tungsten, but the metal is only readily dissolved by either a mixture of hydrofluoric and nitric acids,[2] or, a mixture of phosphoric and perchloric[5] acids.

During part of a programme of work on the chemical analysis of tungsten metal, it became desirable to know the composition of the mixture of hydrofluoric and nitric acids which most rapidly effects solution of the metal, and also to know the nature of the reactions which lead to the dissolution of the metal in the acid mixture. An account of the experimental work carried out on these two topics is given herein.

Experimental

Materials Used

Concentrated Nitric Acid (A.R.)—69% w/w HNO_3

Concentrated Hydrofluoric Acid—55% w/w HF

Sodium Nitrate (A.R.)

Sodium Nitrite (A.R.)

Tungsten Sheet—thickness 100 microns, supplied by Murex, Ltd. The concentrations of the impurities in the metal used in these experiments are stated by the manufacturers to be: iron—0·025%; other elements—traces only.

Effect of Changes in the Composition of the Acid Mixture on the Rate of Solution of Tungsten

Samples of tungsten sheet, weighing 0·35 ± 0·02 g., were allowed to react, in a platinum dish, with 10 ml. portions of the various acid mixtures for convenient lengths of time. They were then washed, dried and reweighed to determine the weight of tungsten which had dissolved.

The experimental results have been plotted in Figs. 1 and 2, and it can be seen that:

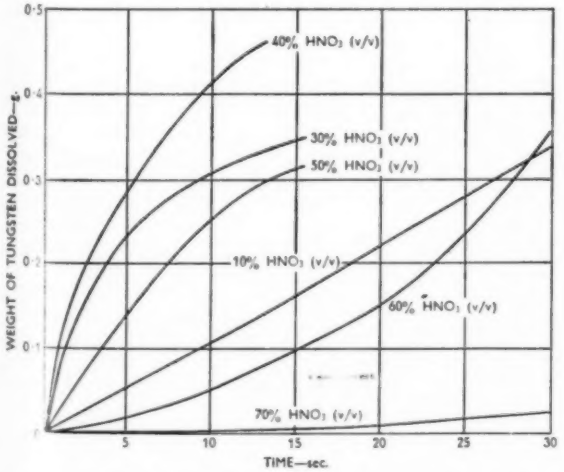


Fig. 1.—The effect of variations in nitric acid concentration on the rate of dissolution of tungsten in HF : HNO_3 mixtures.

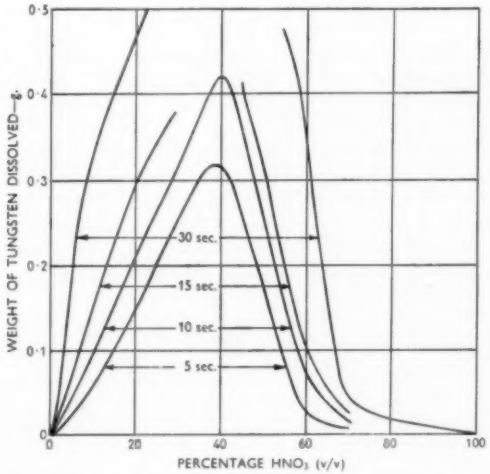


Fig. 2.—The solubility of tungsten in HF : HNO_3 mixtures shown as a function of nitric acid concentration.

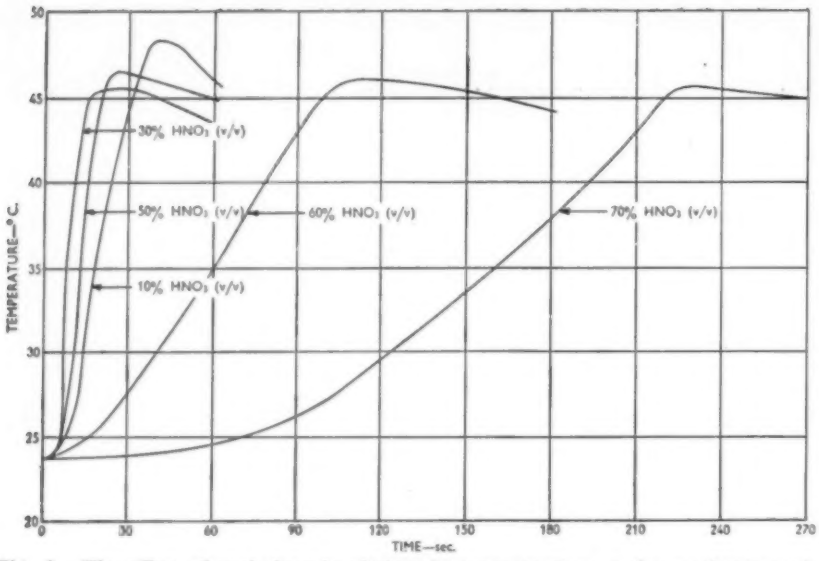


Fig. 3.—The effect of variations in nitric acid concentration on the mechanism of the reaction between tungsten and HF : HNO_3 mixtures.

(*a*) A mixture containing approximately 40% by volume concentrated nitric acid and approximately 60% by volume concentrated hydrofluoric acid is the most effective solvent.

(*b*) Mixtures containing high proportions of nitric acid do not react rapidly with the metal.

(*c*) The slope of the curve (Fig. 1) showing the effect of the mixture containing 70% by volume concentrated nitric acid on tungsten indicates a "period of induction"[6] before the main reaction begins. (The main reaction does not in fact begin during the time interval covered by this particular curve. See Fig. 3).

Effect of Variations in Nitric Acid Concentration on the Mechanism of the Reaction

If it is only the rate of reaction, and not the mechanism of the reaction, which varies as the nitric acid concentration is altered, it can be assumed that the quantity of energy liberated during reaction, and consequently the temperature rise, will be constant in reactions carried out under standard conditions. The only variations will be in the rate at which the energy is evolved.

To confirm that the reaction mechanism is independent of nitric acid concentration, samples of 100μ tungsten sheet, weighing 0·600 ± 0·005 g., were allowed to react with 20 ml. portions of various acid mixtures in a simple polythene calorimeter. The reactions were allowed to go to completion and the temperature rise was noted as the reaction proceeded.

The results of this series of experiments are given in Fig. 3, from which it is clear that :

(*a*) The quantity of heat evolved during the reaction is independent of the nitric acid concentration and, therefore, the reaction mechanism is similarly independent.

(*b*) The rate of release of energy (i.e., rate of temperature increase) is directly related to the rate of reaction, as indicated in Fig. 1.

(*c*) A "period of induction" is evident at high nitric acid concentrations.

Mechanism of the Reaction which occurs between Tungsten Metal and Hydrofluoric Acid-Nitric Acid Mixtures.

When tungsten dissolves in hydrofluoric-nitric acid mixtures, it is converted to the trioxide,[7] WO_3, indicating that the hydrogen fluoride present in the solution has no direct chemical action on the metal and, therefore, that the period of induction and the main reaction result from the presence of nitric acid or its decomposition products.

To examine the possibility that the initial attack on tungsten and the period of induction result from the formation of nitrous acid, or lower oxides of nitrogen, the solubility of the metal in hydrofluoric acid to which sodium nitrite had been added was examined.

A weighed sample of 100μ tungsten sheet was placed in 10 ml. concentrated hydrofluoric acid in a platinum dish and an accurately weighed quantity of sodium nitrite was added. The tungsten sample was removed from the acid at various time intervals and weighed to determine the weight loss. The rate of solution of tungsten in hydrofluoric acid containing sodium nitrite is shown in Fig. 4, from which it is apparent that both the rate of solution and the weight of tungsten dissolved are related to the concentration of nitrite ion.

If sodium nitrite is replaced by sodium nitrate, both the reaction rate and the weight of tungsten dissolved are increased, (Fig. 4), and during the reaction the formation of a yellow/blue colouration around the tungsten sample and the sodium nitrate crystals can be observed. This colouration disperses fairly rapidly into the bulk of the solution and, from its chemical reactions, is assumed to be nitrous acid or its decomposition products, an observation which suggests that the primary reaction is related to the reduction of the nitrate ion. No reaction occurs if urea is added to the hydrofluoric acid-sodium nitrate mixture before the tungsten sample is introduced, and the addition of urea will stop a reaction which is occurring between a sodium nitrate-hydrofluoric acid mixture and tungsten, two facts which confirm the necessity for the presence of nitrous acid or its decomposition products if the reaction is to proceed. The formation of nitrous acid in this particular instance can only be interpreted as resulting from the reduction of the nitrate ion together with a simultaneous oxidation of the metal, according to the equations :

$$6HF \longrightarrow 3HF_2^- + 3H^+ \quad (1)$$

$$W + 3Na^+ + 3NO_3^- + 3H^+ \longrightarrow WO_3 + 3HNO_2 + 3Na^+ \quad (2)$$

$$3HF_2^- + 3Na^+ \longrightarrow 3NaHF_2 \quad (3)$$

Nitrous acid is unstable in solution, dissociating easily by loss of water and by disproportioning :

$$2HNO_2 \longrightarrow H_2O + N_2O_3 \rightleftharpoons NO_2 + NO \quad (4)$$

$$3HNO_2 \longrightarrow HNO_3 + 2NO + N_2O \quad (5)$$

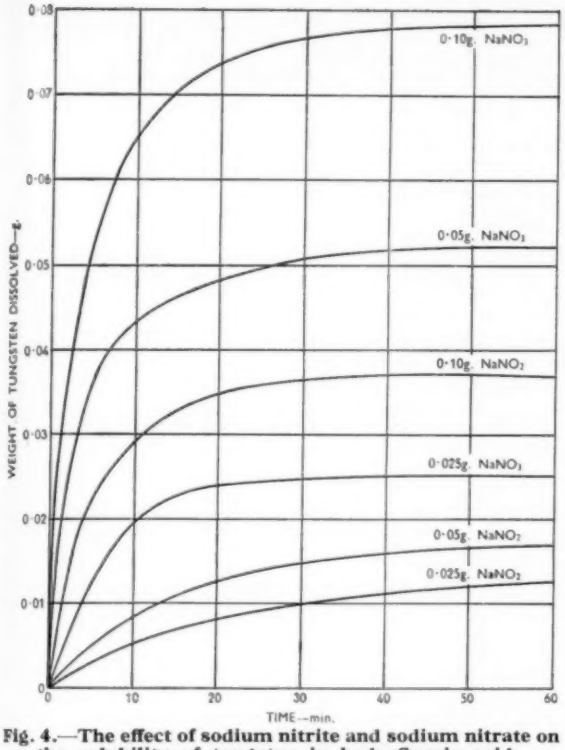


Fig. 4.—The effect of sodium nitrite and sodium nitrate on the solubility of tungsten in hydrofluoric acid.

This last reaction is more complicated than is indicated by the equation and, almost certainly, takes place in steps, which can be summarised as,

$$2HNO_2 \longrightarrow NO + NO_2 + H_2O \quad (6)$$

$$2NO_2 + H_2O \longrightarrow HNO_3 + HNO_2 \quad (7)$$

the latter being the slower and rate controlling reaction.[8]

It is well known that nitrous acid often appears to catalyse the reaction of a metal with nitric acid. Since the suggestion has been made that the active catalyst is actually nitrogen dioxide,[8] a product of the decomposition of nitrous acid, and not nitrous acid itself, nitrogen dioxide was prepared, by the standard method from lead nitrate, and its action on tungsten examined in the following way :

(*a*) The gas was passed over tungsten sheet for 4 hours at approximately 20° C. The only apparent effect was a slight discolouration of the metal surface.

(*b*) The gas was passed over tungsten metal powder for 4 hours at approximately 20° C. There was no noticeable effect.

(*c*) Tungsten sheet was brought into contact with concentrated hydrofluoric acid saturated with nitrogen dioxide. The metal reacted and dissolved.

(*d*) A sample of sheet tungsten was placed in distilled water at approximately 20° C. and nitrogen dioxide bubbled through the solution. Gas bubbles accumulated on the metal, indicating reaction, although there was no significant weight change in the sample after immersion for one hour. It was, however, observed that the surface of the metal had taken on a slight brown colouration.

(*e*) An experiment was carried out under the same conditions as in (*d*), above, but using an aqueous solution of urea in place of distilled water. There was again no weight change in the sample and in this experiment the metal surface had not been affected.

From this series of experiments it can be concluded that nitrogen dioxide and/or nitrous acid reacts with tungsten. The surface coating obtained in (*d*), above, was found to be soluble in alkalies, insoluble in hydrochloric and nitric acids, but soluble in hydrofluoric acid. As an extension of (*d*), above, a sample of sheet tungsten was placed in 60% (v/v) hydrochloric acid, sodium nitrite was added and the mixture was allowed to stand in a stoppered flask for 48 hours at room temperature. The metal surface acquired a distinct brownish coating which had chemical properties identical with those of the coating obtained in (*d*), and which was quite soft and easily scratched with a knife blade to reveal the metal surface.

The precise composition of this film has not been established, but it is almost certainly an oxide of tungsten resulting from oxidation of the metal surface by nitrogen dioxide according to an equation of the form,

$$W + 3NO_2 \longrightarrow WO_3 + 3NO \quad (8)$$

The facile solubility of tungsten in hydrofluoric acid-nitric acid mixtures can, therefore, be explained as being the result of an initial oxidation of the metal surface by nitrogen dioxide producing an oxide film soluble in hydrofluoric acid, but insoluble in other mineral acids.

The nitrogen dioxide responsible for the oxidation of the metal surface can arise either from the decomposition of nitrous acid, as indicated in equations 4 and 5, or from the *in situ* decomposition of nitric acid which proceeds according to the mechanism of equation 9.

$$4HNO_3 \longrightarrow 2H_2O + 2N_2O_5 \rightleftharpoons 4NO_2 + O_2 \quad (9)$$

Since nitrogen dioxide is a product of the decomposition of nitric acid and dissolves in water to produce unstable nitrous acid, it is not possible to define the ultimate origin of the nitrogen dioxide responsible for the primary oxidation of the tungsten surface, i.e., whether it results from the reduction, or, from the *in situ* decomposition of nitric acid.

Summary and Conclusions

Tungsten is most readily dissolved by a mixture containing approximately 40% by volume concentrated nitric acid and approximately 60% by volume concentrated hydrofluoric acid. The metal surface is oxidised by nitrogen dioxide, the oxide thus produced being soluble in hydrofluoric acid, but insoluble in other mineral acids.

Acknowledgment

The author thanks the Directors of the British Thomson-Houston Co., Ltd., for permission to publish this paper.

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An Economical Resistance-Type Controller for Platinum-Wound Furnaces*

By R. J. Newman, A.M.I.E.E.

Development Laboratory, Johnson, Matthey & Co., Ltd.

A temperature controller for resistance furnaces with platinum alloy windings is described, in which the control signal is obtained by monitoring the resistance of the winding, so that no separate temperature sensing element is required. Provision is made for control of the initial heating rate to avoid thermal shock.

IN cases where the expense of a pyrometer controller is not warranted, and where the required long-term accuracy is no greater than say ± 20° C., it has been customary to use an energy regulator which, of course, does not take direct cognisance of furnace temperature. It has, however, the advantage that the energy input may be set to a low level to bring the furnace temperature slowly up to say 600° C. When reset to the energy input required for the working temperature, it is necessary either to wait for several hours until the temperature has stabilised, or to overset initially and then to arrive at the required temperature by the tedious process of successive approximations. The arrangement to be described provides facilities for slow run-up, and also gives sufficiently close temperature control for most routine laboratory work.

The basic circuit diagram for temperature control is shown in Fig. 1. A "raw" rectified D.C. voltage is obtained from a current transformer in the furnace circuit. A voltage having a similar mean value is obtained from the A.C. mains through a further rectifier. These two voltages are connected in series opposition, and the circuit closed through the coil of a sensitive polarised relay. A large capacitor shunts the relay coil to carry unbalanced ripple current. The relay is polarised so that it is operated whenever the voltage derived from the furnace current is higher than the reference voltage. At this time a contact maintains power to the furnace. When the furnace current falls sufficiently to equalise the voltages, the relay will drop out. Since there is now no furnace current, this would be the end of the sequence, but for the existence of a restoring circuit consisting of a neon tube, resistor and capacitor. The neon discharge closes the polarised relay for a short period after a few seconds, and if the temperature is too low the relay remains closed until balance is again achieved between the voltages.

The relay voltage is not fully smoothed by its shunt capacitor, and the residual ripple serves to keep the relay "wetted." With the particular relay used, the discrimination between "open" and "closed" conditions of the relay contacts is about 0·05 volt. The differential for relay operation is about 2° at 1,500° C., and is less at lower temperatures.

The "on" time is dictated by the thermal mass of the windings and adjacent refractory material: also, of course, by the power input at the temperature in question. In a typical case, the furnace may remain "on" for two-second periods at 1,000° C., and for twenty-second periods at 1,500° C.

Possible Sources of Error

There are appreciable sources of error inherent to the arrangement, and these will be discussed in conjunction with the full circuit shown in Fig. 2. Switch positions 1 and 2 are used respectively to run the furnace from cold to about 200° C., in approximately ten minutes, and from 200° C. to 600° C. in approximately twenty minutes, at which time position 3 arranges the circuit for control at a set temperature. The first two positions give "on" pulses of about half a second, spaced by ten seconds in the first case and two seconds in the second case. The timing on position 1 is arranged to give an idling temperature of about 600° C. if the furnace is left to stand-by on this setting.

The third position closes the sensitive relay (if it should be found open) every four seconds, when the balance condition found dictates whether or not it will remain closed. The sensitive relay R operates a slave relay C which is fairly slow to fall out. When balance is near, relay R will tend to "dither," and its mark-to-space ratio will slowly fall until insufficient mean power is supplied to hold C, which will release. When the furnace power is interrupted, the voltage from the current transformer disappears, firmly opening relay R. In order to limit the relay de-energising current which flows in absence of furnace current, a small rectifier is connected across the main coil of R. Also in parallel with the 2,000 ohm coil of R is a thermistor, whose purpose is to prevent excessive dissipation in

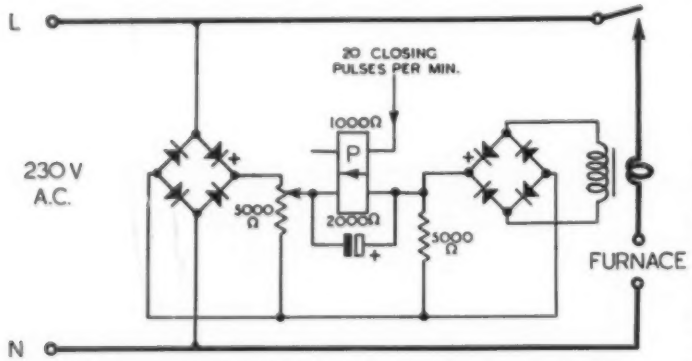

Fig. 1.—Basic circuit diagram for temperature controller.

* Reprinted from *Platinum Metals Review*, 1, 58-60.

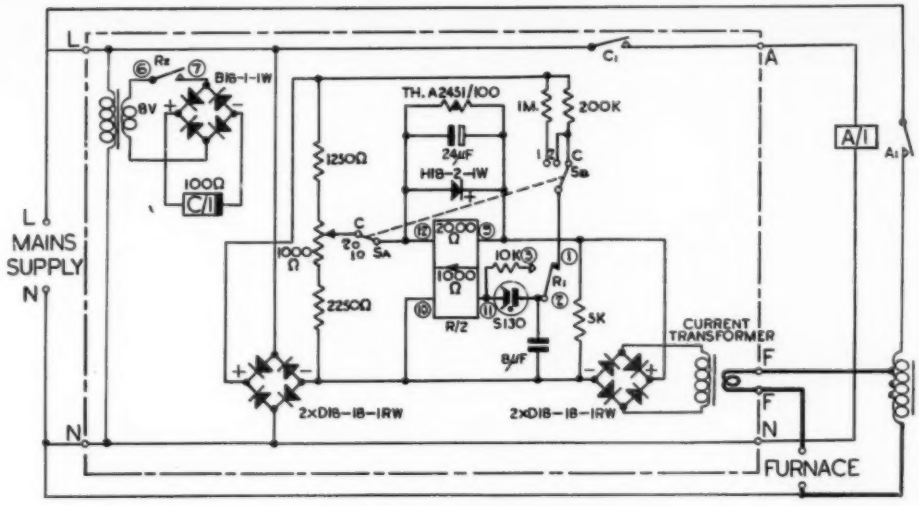

Fig. 2.—Complete circuit diagram.

the coil while running up to a high temperature, during which time there is a large " bridge " unbalance holding *R* closed.

The factors militating against accuracy of temperature control are as follows :—

(*a*) The current transformer uses a core of grain-oriented silicon steel run at a moderate flux density. There is, however, a small departure from linearity of relationship between furnace current and rectified voltage, which in the present model results in a fall of approximately 1° C. for each volt rise in mains potential.

(*b*) Change in supply waveform will affect calibration in that the reference voltage will rise more rapidly with increase of form factor than will the current transformer output. This is unlikely to be of importance when using the mains supply directly, but the output waveform of certain stabilising transformers varies considerably with load, and can cause appreciable errors of control temperature.

(*c*) A slow drift of calibration will occur as the furnace element wire volatilises during its life. This amounts to no more than about 1° C. per 500 hours, and may be neglected since the suggested function of the present instrument is for short-term laboratory work.

(*d*) Change in rectifier characteristics during life may cause a calibration drift of as much as 100° C. in a typical case, if aged rectifiers are used for one side of the " bridge " and new ones for the other side.

(*e*) The design of tubular muffles is usually such that while they are being heated, the rate of temperature rise of the central zone along the axis is more rapid than that of the end zones, although, eventually all reach substantially the same temperature. Therefore, if the present controller is set to act at an element temperature of *T*, " cycling " will commence with the central region at a temperature higher than *T* and end regions lower than *T*. The disparity, which in a typical design may be about 20° C., will take several hours to disappear.

It is advisable to allow a little light from, say, a pilot lamp to fall on the neon tube so as to stabilise the breakdown voltage.

Conclusions

This device is cheaper to produce than most orthodox temperature controllers, and the accuracy is sufficient for many purposes. The absence of a thermocouple or other sensing element in the hot zone is often advantageous. Occasional temperature checks must, of course, be made with a probe thermocouple, but the life and accuracy of the latter are not impaired by long subjection to high temperature or possibly inimical atmosphere.

Acknowledgment

We are indebted to the Editor of *Platinum Metals Review*, for permission to reprint this article, and for the loan of the diagrams.

Owen Organisation in South Africa

THE Owen Organisation have recently extended their group of companies to the Union of South Africa by the formation of Rubery, Owen & Scott (S.A.), Ltd. This firm will be responsible for the manufacture and marketing of certain products of the Owen Organisation which will initially include steel pallets, trailer axles, washing machines, steel nuts and bolts and Easiclene domestic equipment.

MR. A. G. B. OWEN, C.B.E., Chairman of the Owen Organisation, will be Chairman of the new Company. His brother, MR. E. W. B. OWEN will be Vice-Chairman, with MR. J. SCOTT as Managing Director. The address will be : Rubery, Owen & Scott (S.A.), Ltd., 19–49 Scott Road, Congella, Durban.

Welding Company Acquired

FRANCIS MORTON & CO., LTD., constructional engineers, of Liverpool, have acquired the issued capital of Bates & Bates, Ltd., of Birmingham, specialists in welding and welding controls. MR. C. R. BATES continues as Managing Director.

Electron Microscope for Alloy Steel Research

Siemens Unit at Swinden Laboratories

FUNDAMENTAL studies of the structural changes in alloy steels will receive a further impetus as the result of the installation of a Siemens II electron microscope at the Central Research and Development Department of The United Steel Cos., Ltd. With this new equipment it will be possible to obtain magnifications of up to × 100,000.

The principle of operation of the microscope is that a high voltage beam of electrons is discharged from a source unit through the specimen focussed in a series of magnetic lenses and finally projected on to a fluorescent screen to produce a visible image. The amount of magnification is controlled by the strength of the magnetic field in the lenses, and it is possible to obtain magnifications in stages from × 300 to × 30,000. Photographic enlargement can then increase this magnification up to × 100,000, with a resolution of 30Å.

It is not possible to pass an electron beam through a thick metal specimen and it is therefore necessary to use a replica. Very great progress has been made in replica techniques in the last year or two, which has considerably extended the use of the electron microscope in metallography. The original technique used a thin film of plastic which could be stripped from the etched metal surface and examined in the microscope. These plastic replicas have the disadvantage that they tend to polymerise in the electron beam, which introduces a structure in the plastic film itself and destroys the finer details of the replica. Because of this feature the maximum magnification which can be used with a plastic replica is about × 10,000.

If carbon is used as a replica material, however, this disadvantage is overcome. Carbon replicas are extremely strong and no change in structure is produced by the electron beam. Consequently, magnifications up to the full limit of the microscope can be used. Carbon replicas can be made either by depositing a layer of carbon on a plastic replica and then dissolving the plastic film away or, alternatively, by depositing the carbon directly on to the metal surface.

It is likely that the electron microscope will have two important applications in the examination of metal structures. The first of these is where the magnification required is just outside the range of the optical microscope, i.e. up to × 5,000. This degree of magnification will be extremely useful for the examination of fine metallographic structures such as martensite and bainite. The other main application will use the highest magnifications to examine extremely small particles, such as carbides, at the beginning of a precipitation process. These dispersions of fine carbide particles are very important in controlling metallurgical properties such as creep strength and it is not possible to examine them by any other means.

Electronic Computer for Morgan

A HEC General Purpose Electronic Computer, made by the British Tabulating Machine Co., Ltd., has been installed in the Battersea headquarters of the Morgan Crucible Co., Ltd., following three years' study and evaluation by the Morgan Crucible investigation team on the particular problems which the computer would be called upon to solve.

At present it is being used to prepare and analyse salaries and payrolls of the Company's employees. Tasks on which it will be used within the near future are the preparation of customer statements, invoice analyses, and the control and analysis of stock—the company makes 20,000 different items which are ordered in quantities of from two to half a million—and also certain aspects of quality control. It will also carry out mathematical work for the Company's Central Research Department.

1958 I.E.A. Exhibition

So great has been the number of potential exhibitors, and the advance interest shown throughout the industry in the first Instruments, Electronics and Automation Exhibition—to be held at Olympia in May of this year—that it has already been agreed to stage the show again next year. Dates will be April 16th to 25th, 1958, and the location will again be Olympia.

Spanish Orders for English Electric

THE English Electric Co., Ltd., has received a further order from the Spanish National Railways (R.E.N.F.E.) for fifteen 3,600 h.p., 3,000-volt D.C. electric locomotives. The Vulcan Foundry, Ltd., of Newton-le-Willows, Lancashire, will make the mechanical parts for the locomotives, which will weigh 118 tons each.

A further order for electrical equipment for the Aviles Steel Works, in the North of Spain, has also been received. The Company has already executed orders amounting in all to about £1,500,000 for mill drives, distribution and rectifier equipment for the Aviles Steel Works, which is the largest project of its type in Spain. The value of the new locomotive and steel mill electrical equipment orders is approximately £1,800,000.